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The Vulnerability of Mobile Telecommunications to Natural Hazards

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Executive Summary

The federal government has assigned high priority to Canada becoming one of the most "connected" telecommunications countries in the world. Canada's advantages as a potential world leader in telecommunications, including mobile, Internet, and wireline services, are clearly evident. For example, we have excellent fibre optic trunked wireline services throughout the country, state-of-the-art and competitive cellular services with coverage in populated areas, and wide-area Public Safety and Public Service telecommunications networks in most provinces.

These latter networks are critical to Canada's response to and recovery from natural disasters. Unfortunately, while the responsibility for implementing Public Safety telecommunications networks typically resides with local governments, as does the initial responsibility for responding to natural disasters, the capabilities and standards of existing Public Safety systems vary widely across the country. Lack of adequate funding at the municipal, regional, and, occasionally, at the provincial level, often hinders the efforts to offer a grade of service on the Public Safety telecommunications networks that meets Public Safety standards.

In smaller municipalities, in particular, aging local telecommunications infrastructures serve Public Safety and Public Service organizations. These infrastructures are becoming increasingly difficult to maintain as they do not provide interoperability between agencies, and they lack redundancy for essential elements. This makes them susceptible to failure under adverse or extreme conditions such as occur in natural disasters.

This report examines the potential vulnerability of the mobile telecommunications infrastructure in Canada to natural hazards, and identifies a number of concerns relevant to emergency preparedness and management. It provides an overview of the general principles of mobile network design and includes information on both private and public mobile radio networks. The report also identifies the components of the telecommunications infrastructure and their potential vulnerability to natural hazards, thereby allowing emergency managers to reasonably assess the vulnerability of their local surroundings.

Central to the report is the examination of the various types of mobile radio systems on a province-by-province basis, with emphasis on natural hazards specific to each province and their potential effect on the existing mobile telecommunications networks. The report is supported by two case studies – one highlighting a network from the West Coast, the other a network from the East Coast – which show how natural hazards and their potential impacts differ across the country. The case studies examine a regional versus provincial approach to providing mobile communications networks to Public Safety and Public Service agencies and provide a methodology for prioritizing the mitigation of these networks' vulnerability to natural hazards.

Fortunately, Canada has experienced relatively few natural disasters compared, for example, to the United States. Although our incidence rate is relatively low, history and scientific research show that Canada will not only continue to face the threat of natural disasters but that the devastation – including loss of assets and life – from some of these events in the future could be far greater than we have experienced in the past. And as Canada becomes even more urbanized,

we face the potential for even greater losses because of the greater concentration of people and assets, including telecommunications, in urban centres.

Adequate, interoperable, and coordinated telecommunications systems are critical to the response to and recovery from the impact of natural disasters. Canada has recently made strides to build provincial Public Service wide-area networks that, with some enhancements, can support Public Safety agencies, thereby at least providing interoperability between Public Safety agencies and Public Service departments. In many jurisdictions, the lack of interoperability between Public Safety networks deployed in the same geographical area also makes mobile communications systems vulnerable to all types of hazards.

Some of this report's findings with regard to the vulnerability of mobile telecommunications to natural hazards were expected; however, others were surprising and could lead to new perceptions of the vulnerabilities of Canada's mobile radio systems. Presented below are some of the report's major findings.

- Mobile wireless communications are essential to any coordinated effort to minimize loss of life in emergencies, and for general emergency management.

- Public Safety and Public Service mobile communications networks vary widely in terms of size, funding, and technical standards.

- The vulnerability of Public Safety and Public Service systems to natural hazards has a low priority with virtually all of the municipal systems consulted in this study.

- Public cellular and PCS mobile networks are efficient under normal circumstances, but are vulnerable to uncontrollable overloading in emergencies and disasters.

- In the past, public telecommunications networks (cellular, PCS) have experienced overloading in heavily populated areas immediately following a disaster. However, their availability to first responders in emergencies that last for an extended period has been useful in recovery from natural disasters where a large number of landlines were out of service.

The mobile communications sector is constantly evolving. At the time this report was drafted (February 2002), local/provincial governments and public safety agencies were working toward improving their capabilities to respond to major emergencies. But more work remains to be done if emergency planners are to mitigate the potential vulnerability of mobile telecommunications to natural disasters. This report therefore recommends the following:

- Municipalities should be encouraged to upgrade their mobile radio networks to shared systems and, where the size of the system is appropriate, to strongly consider trunked architecture. If practical, their legacy systems should serve as a back-up. Training and simulations of natural hazards would help identify vulnerabilities in the current systems. The training already in place at the provincial and regional levels should continue.

- Continued effort should be made to quantify the impact of natural disasters on mobile radio systems (particularly on Public Safety and Public Service systems) and to examine the lack of priority that municipal and other Public Safety networks assign to disruption caused by natural hazards.

Glossary of Terms and Definitions

Airtankers	Aircraft used in forest firefighting that carry water or fire retardant to remote locations.
Alphanumeric dispatch services	Short messaging
AMPS	Advanced Mobile Phone System
Analogue	A form of transmission in which the level can continuously vary; natural speech is an example of an analogue signal.
Anchor tenant	The first and, usually, a major user of a shared mobile radio system. Typically the anchor tenant provides the initial financial justification for the system, usually in the expectation that there will be additional future users of the system.
APCO	Association of Public-Safety Communications Officials
Backhaul	Landlines (typically T1 or fibre optic) or microwave links connecting customer-premises equipment with a distant station.
Band	A group of wireless frequencies
Base station	The central radio transmitter/receiver that maintains communications with mobile units and also with the PSTN.
BER	Bit Error Rate – the ratio of received bits that contain errors to the total number of transmitted bits.
Blackberry™	A type of cell phone capable of transmitting and receiving emails.
CASARA	Civil Air Search and Rescue Association
CDMA	Code Division Multiple Access – Spread spectrum method of enabling multiple users to share the radio frequency spectrum by assigning each active user an individual code.

CDPD	Cellular Digital Packet Data – a data transmission technology (800-900 MHz) developed for use on cellular networks to transmit data in packets via data transfer rates of up to 19.2 kbps.
CID	Criminal Investigation Department
CIFFC	Canadian Interagency Forest Fire Centre
Coaxial cable	An electrical transmission cable capable of carrying many TV, voice or data channels.
COG	Coordination and Operation Group
CRD	Capital Regional District
CREST	Capital Regional Emergency Services Telecommunications network (BC)
CRTC	Canadian Radio-television and Telecommunications Commission
DAQ	Delivered Audio Quality
Data link	A point-to-point wireless or wireline trunk dedicated to the carriage of data.
DCO	District Communications Officer
DGT	Direction générale des télécommunications
Digital	A form of transmission in which the information must be in the form of zeroes and ones; computer data is inherently digital in nature, but may be converted to analogue (via a modem) if transmission uses an analogue channel.
Digital voice coder	A device for taking a normal (analogue) voice signal and converting, or coding, it to digital form so that it may take advantage of digital transmission systems.
Earth observation satellites	Satellites designed to take electronic images of the earth at various frequencies including visible light.
E-Comm	Emergency Communications Centre: Vancouver
EDACS®	Enhanced Digital Access Communications Systems
EHS	Emergency Health Services

EMO	Emergency Measures Organization
EMS	Emergency Medical Service
EOC	Emergency Operations Centre
EPS	Edmonton Police Service
ESA	European Space Agency
Evergreening	The technology of designing a telecommunications or radio infrastructure such that it can be upgraded as new technologies are developed without requiring complete replacement.
FDMA	Frequency Division Multiple Access
Fibre optic	Landline cables that use glass fibres to carry very large amounts of information in the form of pulses of light. Also occasionally used to carry analogue signals in the form of light.
Fibre optic trunking	The use of an optical fibre (highly-refined glass) to carry a very large number of voice, data, or video signals from one point to another. These are typically, but not always, carried in digital rather than analogue form.
Fibre ring networks	The use of fibre optic trunking connected end-to-end and running through all required distribution points. All of the optical amplifiers within the fibre ring network are two-way. As optical fibres are vulnerable to being cut by heavy equipment (they are typically buried), a two-way fibre optic ring provides full redundancy so that if the fibre optic trunk is cut at one point, the signals will automatically be routed in the opposite direction.
FleetNet™ system	Province-wide networks
GEOCC	Government Emergency Operations Coordination Centre
GHz	Gigahertz (a thousand million cycles per second)
Globalstar™ satellite fixed phones	Mobile satellite system user's base stations

GMCO	Government Mobile Communications Office
GOS	Grade of service
GPS	Global Positioning System
GSAR	Ground Search and Rescue
GSM	Global System for Mobile Communications
GVRD	Greater Vancouver Regional District
HVAC	Heating, ventilation, and air conditioning
IC	Industry Canada
iDEN™	Integrated Digital Enhanced Network – A wireless technology developed by Motorola that works in the 800 MHz, 900 MHz and 1.5 GHz radio bands. The technology supports, on one handset, voice (both dispatch radio and PSTN connection) numeric paging, Short Message Service (SMS), and data and fax transmissions.
IMBE	Improved Multi-Band Excitation
Incident Command	A group of representatives from various Public Safety and other agencies that coordinates response to an incident.
Interconnection	The routing of telecommunications traffic between the networks of different communications systems.
Linear links	Links that run from point-to-point rather than in a ring or other redundant form.
MDMRS	Multi-Departmental Mobile Radio System
MHz	Megahertz (millions of cycles per second)
Microwave	An ill-defined band of radio frequencies usually taken to be between 1 GHz and 100 GHz, but characterized by the fact that the wavelength is comparable to the size of physical electronic components.
Microwave backbone system	Radio links connecting various transmit/receive sites in a network operating in various gigahertz frequency bands.

Mike™	Public dispatch-based mobile network
Mobile command post	Typically a van containing radio equipment, generator, telephones, fax and other equipment necessary to provide communications between field personnel and a group of selected officials coordinating response to an incident.
MSAT	Mobile Satellite
MSC	Meteorological Service of Canada
MTS	Manitoba Telephone System
MTTM	Maritime Tel & Tel Mobility
Multicast	Simultaneous distribution of voice or data to a defined subset of all receive points in a network. The subset may be redefined for each transmission and range from one to all receive points.
Narrowbanding	A technology being implemented in the VHF band to reduce the bandwidth of each occupied channel and thus increase the number of channels available in the VHF radio mobile or radio frequency assignments.
NBCC	National Building Code of Canada
NOAA	National Oceanic and Atmospheric Administration
NRC	National Research Council
NSARA	Nova Scotia Amateur Radio Association
NSIMRS	Nova Scotia Integrated Mobile Radio System
OCIPEP	Office of Critical Infrastructure Protection and Emergency Preparedness
Omnidirectional antenna	An antenna that transmits and receives equally well in all directions, usually on one plane.
OPP	Ontario Provincial Police
PAC	Province of Alberta Communications
Paging	One-way messaging service

PCS	Personal Communications System – public wireless network operating at the 1.9 GHz range
PEP	Provincial Emergency Program
PMCC	Provincial Mobile Communications Centre
PNS	Province of Nova Scotia
Portable	Handheld radio
PSAP	Public Safety Answering Point
PSTN	Public Switched Telephone Network
Public Safety Services	A term used generically to describe Police, Fire, Ambulance and Emergency Preparedness organizations.
Public Service Organizations	A term used generically to describe those services, typically under the responsibility of a municipality, region, or province, that serve the public good, and in the case of this report, require mobile communication systems. Typical of these are Corporate Departments, Public Works, Fleet Management and, in many cases, Electrical Utilities, Gas Utilities, and Water.
Radio amateur network	A radio communication service for the purpose of self-training, intercommunication and technical investigations carried out by amateurs, that is to say, by duly authorized persons interested in radio technique solely with a personal aim and without pecuniary interest.
Ray dome	A cover for a parabolic antenna that is transparent to radio waves.
RCMP	Royal Canadian Mounted Police
REMSAT	Real-time Emergency Management via Satellite – a pilot project using satellite communications, location equipment, and data from Earth observation satellites to manage emergency operations in remote areas.
Repeater	Amplifier and the associated equipment used to receive, process and transmit a signal.
RF	Radio frequency

Ring configuration	Communications links capable of reversing traffic flow in case of a break along the regular path.
RMOC	Regional Municipality of Ottawa-Carleton
Self-healing fibre loops	Fibre optic links capable of carrying traffic in both directions (in case of an accidental cut, the traffic can flow in the other direction without interrupting communications).
Simplex	In simplex operation, one terminal of the system transmits while the other terminal receives.
Simulcast	SIMULtaneous broadCAST by two or more transmitters located at different sites operating on the same RF frequency but within interference range of each other. Simulcasting requires precise RF frequencies, audio responses and synchronized data. A Simulcast trunked cell consists of two or more transmitting sites. Each site has the same number of channels and uses a common set of RF frequencies.
SmartZone™ trunking system	Motorola system that links several zones together.
SONET	Synchronous Optical NETwork
SPCUM	Service de police de la Communauté urbaine de Montréal (Montréal Urban Community Police Department)
Spectrum Management	The overall task of ensuring that the radio frequency spectrum is managed and used in accordance with the national and international regulations in force.
Switching Facilities	Typically, a building containing telephone switches and radio equipment.
T1 line	A telecommunications line (wire, co-axial or fibre) capable of carrying 24 digital voice channels or 1.536 Mbps of digital data.
TDMA	Time Division Multiple Access – a technique that assigns each subscriber desiring service a different time slot on a given frequency.

Telecommunications	By definition, distant communications. More specifically, the use of the radio spectrum, wires, or *fibre optic cable to communicate* sound, images, or data, or any combination of these, between separate locations.
Terrestrial Microwave	Point-to-Radio links between distant sites operating in one or more of the gigahertz bands.
TETRA	Terrestrial Trunked Radio – a European-developed mobile system standard.
TIA	Telecommunications Industry Association – organization developing standards related to telecommunications.
TMRS	Trunked Mobile Radio System – Nova Scotia province-wide system operated by Maritime Mobility.
Toll switch	Main switching facilities
Trunked	A telecommunications connection between two exchanges, switches, central offices, or data concentration devices.
Trunking zone controller	Central RF equipment that determines the flow of traffic in a network.
TX/RX	Transmitter/Receiver
UPS	Uninterruptible Power Supply – back up power.
Vehicular repeaters	Repeaters installed in vehicles to extend radio coverage or to provide coverage in another frequency band.
VHF	Very High Frequency
Wide Area Wireless Networks	Networks that allow radio communications over large areas, typically a whole province.
Wireless	The use of any part of the electromagnetic spectrum (but usually the radio spectrum) to transmit and/or receive sound, images, or data, or any combination of these, between one point and one or many points. Typical examples are television and radio broadcasting; cellular telephones; and satellite communications.

Wireline	The use of fixed wires, cables or optical fibres to transmit and/or receive sound, images, or data, or any combination of these, between one point and one or many points. Typical examples are the telephone network, the cable television network, and Internet.

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1.0 Project Objectives and Scope[1]

The objective of this work is to address, to the extent practical, a number of issues pertaining to telecommunications networks in Canada that directly affect emergency management, preparedness and emergency measures. The intent is that the document be used by Canadian emergency preparedness and Public Safety organizations to support both their operational and training activities related to communications. Additional objectives include ensuring that developing technologies are taken into account; that the databases are updateable; that it serves as a tool to identify current emergency telecommunications weaknesses in a manner that permits them to be overcome; and that it offers a practical, usable set of deliverables for planning, operations and training.

This work examined Public Safety and Public Service telecommunications networks, at both provincial and municipal levels, which already exist or are currently being implemented. Identification of the strengths and weaknesses of the systems evaluated during the study may contribute to reducing their potential vulnerability. It was not part of this work to address in detail the last resort emergency telecommunications resources (i.e. mobile command posts, radio amateur networks, etc.) deployed when a large portion of a particular telecommunications infrastructure fails. However, also included is an examination of the strengths and weaknesses of public networks (Cellular and PCS) for use in natural hazard emergencies.

2.0 Methodology and Format of Deliverables

While the main area of investigation was aimed at Public Safety and Public Services telecommunications vulnerability, much of the information on such networks, in particular those driven by police requirements, is not in the public domain. Similarly, information regarding specifics of public networks is of a highly competitive nature and again is not in the public domain. Furthermore, provinces, municipalities, and major cellular companies do not release detailed information on coverage and networks without non-disclosure agreements. For these reasons, the focus of the project was operationally limited in obtaining the maximum amount of useful information that could be garnered from specialized, public domain sources.

Experience has shown that such information is most appropriately classified by province and, within each province, by private (Public Safety and Public Service) networks and by public networks. The key parameters that were unavailable due to ongoing confidentiality concerns include, to a greater or lesser extent, the location of towers, backhaul facilities, frequencies used, as well as switch location and vulnerability. A major effort was made to contact (personally and by phone) emergency planners and managers across Canada to obtain as much relevant information on their networks as possible. The result of this research is this report and the databases (Appendix B). These can be reviewed and used either together, or as individual tools. All databases are designed to be updateable using a simple process as additional data becomes available. The column headings selected for information archiving, manipulation and retrieval

[1] See Bibliography, Item 1.

are given in the relevant contents lists. The current contents lists of these databases are given in Appendix B.

This set of deliverables is designed to form a baseline of mobile telecommunications network information and their vulnerabilities for future use. It should be noted that due to the wide variation of Public Safety and Public Service networks, the classification of each network into a geo-spatial vulnerability layer has not been practical. However, the spreadsheets provide all currently available information to permit emergency managers to assess the likely vulnerability on a case-by-case basis.

The third section of this report, which discusses the general principles of mobile network design, provides general information on all types of mobile radio networks, both private and public. For those readers whose experience falls outside the mobile communications networks field, a detailed review of this section is recommended as an aid to understanding the rest of the report.

The introduction section provides a brief background to natural hazards and past disasters in addition to an outline of the emergency management and mobile communications network structure. While information on current standards for Public Safety communications is provided, perhaps the most important section of the introduction is the one giving the vulnerability of specific elements of telecommunications infrastructures to natural hazards on an element-by-element basis. The fifth section provides what is perhaps the key information package: the various major mobile communications radio systems and their vulnerabilities presented on a province-by-province basis.

Finally, two networks were selected as case studies to provide additional information where this is available. They also provide a methodology for prioritizing the mitigation of vulnerabilities. Their selection was made based on regional differences, for example, the Capital Regional District situated on the West Coast and the Province of Nova Scotia on the East Coast, on their exposure to different natural hazards, and on the regional versus provincial approach to providing mobile communications networks for use by Public Safety and Public Service agencies.

While the Province of Nova Scotia's Trunked Mobile Radio System (TMRS) is an example of a recently implemented provincial network, the Capital Regional District is just embarking on the implementation of a new regional network. In the meantime, the old communications systems are still operational in the Capital Regional District and allow us to highlight the differences between their past and current performance and vulnerabilities and the new system's expected performance. The latter incorporates a number of features to mitigate the past vulnerabilities, particularly with regard to the earthquake threat.

In addition, the following databases were created for this study:

- Public Safety and Public Service networks (private networks)
- Public networks (cellular, PCS and public dispatch-based networks)
- Public paging networks

A listing of the individual networks for which information and the data columns are provided can be found in Appendix B.

3.0 General Principles of Current Terrestrial Mobile Network Design with Particular Emphasis on Public Safety Networks and Mechanisms for Mitigating Natural and Other Hazards[2]

Given the wide potential audience of this suite of information tools, it was felt appropriate to provide a general review of current terrestrial mobile networks in Canada prior to discussing the individual networks themselves. This includes design options, economic strategies, vulnerability mitigation approaches and the technologies used for both public and private networks. Particular emphasis is given to Public Safety networks, their vulnerability to natural hazards and the methodologies currently used or available to mitigate these vulnerabilities.

3.1 The Need for Mobile Radio Networks

One of the major social changes over the last century has been one of radically increased mobility in all elements of the economy. Driven by the huge advances in transportation (roads, rail, sea and air), this all-pervasive social and economic phenomenon has brought with it the need for essentially instant communications at any time and between any two or more places. The advances in radio communications have kept pace with the mobile environment to fulfill this mobile communications need.

These mobile radio (wireless) needs and advances have occurred to such an extent over the last several decades that mobile communications are now considered a critical infrastructure in the land, sea, and air environments.

It is, of course, an essential part of all Public Safety organizations and the vast majority of Public Services, an intrinsic part of many commercial activities, and, over the last fifteen years, a significant element of the social fabric. The use of cellular phones for both voice and short messages is now becoming all pervasive. It is primarily the social use of cellular and Personal Communications Systems (PCS) that has led to the major increase in the use of these services.

3.2 Main User Groups

In any review of the use of mobile radio communications, it rapidly becomes apparent that the users as a whole can be broken down into the following prime classifications:

- Public Safety and Public Service private networks;
- Commercial private networks; and
- Public networks.

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[2] See Bibliography, Item 46.

For the purpose of this work, private networks are those to which use and access is restricted to a defined group of users, whereas public networks are those available to any member of the public prepared to pay a user fee and to obtain the appropriate user equipment (cell phone, PCS phone, Blackberry™, etc.).

As indicated above, private networks can be conveniently classified as Public Safety and Public Service networks or commercial networks. Public Safety and Public Service networks are those aimed at serving the *common good* and are typically owned by, or controlled by, various levels of government or by government agencies such as Police Forces.

Commercial mobile radio networks are those implemented to fulfill a specific commercial requirement. While this covers a huge range of applications, the most obvious to the public view are those such as taxi networks, courier networks, and delivery networks such as pizza delivery and similar service providers. Commercial networks range from small systems with one or two portable units accessing a simple dispatch centre to nation-wide (and indeed in some cases North America-wide) networks operated by organizations such as Purolator and Federal Express. These commercial networks vary to a great degree, are not listed in any accessible form, and are available only to employees of the companies concerned. As such, they do not play any significant role in natural disaster management and therefore will not be considered further in this work.

Prior to a more in-depth discussion of Public Safety, Public Service, and public networks, it is appropriate to discuss the importance of the radio spectrum and its management and uses, together with the key Public Safety and Public Service technologies which are the major agents of recent change.

3.3 The Radio Spectrum and Its Allocation

For any fixed or mobile radio service of any type to operate it must use the radio spectrum. In other words, it must use a specific frequency or band frequencies which are common to the entity with which it is communicating. While this appears self-evident, the allocation of the frequency spectrum, its technical attributes and the management of such spectrum to ensure that users do not interfere with each other are fundamental elements of all fixed, mobile and broadcast networks.

Since radio waves are electromagnetic radiation travelling in straight lines from their source, they know no political boundaries. If the same or similar frequencies are used simultaneously by two entities at any geographic point where both emissions can be received, they will interfere with each other, usually effectively destroying the information carried by each. From the viewpoint of basic physics, if a radio transmitter is located at a source point in free space, its radio emissions will radiate in a spherical manner throughout the universe for all time (radio astronomers can receive radio signals from the beginning of the universe, i.e. the Big Bang). Thus, the power of a radio signal is determined by its initial strength and by the inverse square of the distance from the transmitting source.

On the ground and in practical situations, there are many modifiers to this law of basic physics. To permit the radio spectrum to be used in a practical and non-interfering manner, an international body – under the auspices of the United Nations and designated the International Telecommunications Union (ITU) – was set up over a hundred years ago to control the use of telecommunications on a world-wide national basis to the benefit of all. The ITU is divided into *two elements: the ITU-T, concerned with wireline (copper wire and optical fibre)* communications, and the ITU-R, concerned with radio communications of all types.

ITU-R meets every three years to allocate both the use and geographic coverage (power) of all parts of the radio spectrum on a national basis. The agreements reached at these meetings have the force of treaties and are rigidly adhered to by all nations to the benefit of all. From these national allocations the designated Public Service entity (in the case of Canada, Industry Canada) makes available specific frequency allocations for carefully specified applications by the means of radio licenses. Any user of the radio spectrum who does not hold an Industry Canada license or is operating outside of the frequency, power, bandwidth and other parameters of that license is open to severe penalties.

For ease of spectrum management, both the ITU-R and Industry Canada break down the use of the spectrum into specific applications such as land-based mobile communications, point-to-point land communications, broadcasting, marine mobile communications, satellite-based mobile communications and the like. This section is only considering spectrum in the land mobile service, details of which are published by Industry Canada.[3] Within the Land Mobile Service allocations, Industry Canada dedicates specific portions of the bands in which Public Safety services have priority. These are given in Figure 1.

[3] See Bibliography, Item 8.

Figure 1 Public Safety Mobile Communications Frequency Bands

Frequency Pairs	Function
138–144 and 148–174 MHz	(VHF) Commonly used by Fire Service and for wide area networks.
406.1–430 and 450–470 MHz	(Lower UHF) Limited number of channels, not greatly used.
806–824 / 851–869 MHz	(Upper UHF or 800 MHz) Commonly used by Public Safety and Public Service.
896–901 / 935–940 MHz	(900 MHz) Comparatively new band used for many applications.
(Future) 764–776 / 794–806 MHz	(700 MHz) A future band for Public Safety and Public Service when vacated by TV broadcasting.

Industry Canada uses various mechanisms for radio spectrum licensing, dependent in part upon the application. Traditionally this was on a *first come, first served* basis for a fixed fee. As the spectrum became congested with the proliferation of fixed and mobile radio services, Industry Canada had to resort to other spectrum management approaches. The original *first come, first served* for a small fixed fee policy was changed to license fees based, for example, upon the amount of spectrum used, the size of the network and the number of network users. Typically, this mechanism is still used for Public Safety, Public Service and many commercial networks.

Given the huge commercial value of public radio networks (cellular and PCS), a comparatively recent allocation method used by Industry Canada is that of spectrum auctions. In this mechanism, licenses are granted to the highest bidder meeting various technical and economic criteria. These auctions generate billions of dollars for the public treasury.

In summary, all users of the land mobile service must obtain licenses for the use of the spectrum and, as a condition of license, must meet technical conditions typified by maximum power, maximum coverage, specific frequencies allocated, frequency stability of the transmitters and limitations on spurious emissions outside of the frequencies allocated. In addition, conditions for economic stability and for the actual beneficial use of the spectrum are also imposed. It should be clearly recognized that the spectrum is a finite but re-usable natural resource.

3.4 A Summary of Key Public Safety and Public Service Mobile Communications Technologies[4]

A number of key technologies have been developed over the last decade to improve mobile communications for (primarily) Public Safety and Public Service applications. These technologies are given in Figure 2 below. A brief summary of each is provided, with their advantages for specific applications and their disadvantages.

Figure 2 Recent Key Public Safety Technical Advances
(Source: Lapp-Hancock Technical Presentation to the Kingston Police: September 2001)

• **Digital Systems**
• **Analogue and Digital Trunking**
• **Encryption Capability**
• **Interoperability (through Trunking)**
• **Simulcast Systems**
• **The Development of Public Safety Standards**
• **The Availability of Specialized User Terminals**

3.4.1 Digital Systems

Over the last five to ten years digital systems have become available for Public Safety mobile communications. The prime advantages of such systems are better voice clarity, especially near the edge of coverage; greater spectrum efficiency in that several channels can be accommodated in the same spectrum as one analogue channel; the capability of encryption at a very high level. Even without encryption, digital systems are far more difficult to intercept with inexpensive scanners than are analogue systems. Finally, it is relatively straightforward for digital radio sets to have analogue capability to make use of legacy equipment.

3.4.2 Analogue and Digital Trunking

Perhaps the most important new technology for mobile communications is that of trunking. Public Safety and Public Service systems are typically allocated a small number of radio frequencies. In a conventional system, each of these frequencies will be allocated a specific task. Police, for example, will use one frequency for patrol activities while another will be used for CID activities. As only one application can use one channel at a time, and any one channel is only used comparatively infrequently, this makes for inefficient use of the radio spectrum, limiting the number of users on a particular network.

By combining wireless and computer technology, it is possible to arrange all available frequencies to be in a pool of frequencies. Thus when a frequency is required by a user of any type, any frequency not in use can be allocated, making far greater use of the spectrum available.

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[4] See Bibliography, Item 52.

This approach is termed trunking. Trunking also permits the splitting of all users, whether they be Police, Fire or Ambulance, into talk groups that can converse with each other but cannot be heard by other talk groups. This allows the sharing of a network by a number of users (Police, Fire, Public Works, etc.) without the other users being either interfered with or of any given user being aware that the network is being shared, other than with their own talk group.

Trunking is available for both analogue and digital systems. An empirical rule of thumb for the breakeven size of system where trunking technology becomes useful is around 300 users.

3.4.3 Encryption Capability

Police, and on occasion other users, require their mobile radio systems to be protected against eavesdroppers. This can be addressed in digital systems by the hard encryption of the digital signal. This has been one of the main drivers for the use of digital systems as, in many Public Safety networks, Police requirements tend to take precedence.

3.4.4 Interoperability

On occasion, it is important that the different Public Safety services be able to communicate with each other. An obvious example is a bad traffic accident requiring the services of Police, Fire, and Ambulance. To accommodate this, a small number of mutual aid channels have been allocated with typically one channel being available in any given geographic area. Because of lack of common coverage between services and other constraints, interoperability tends to be a problem with conventional systems. In trunked systems, both analogue and digital, a specific talk group can be allocated to interoperability, thereby overcoming these limitations.

3.4.5 Simulcast Systems

Another significant advance in technology has been the so-called simulcast system. In this technology a number of base station transmitters in a given city or region are synchronized and transmit simultaneously on the same frequency. Technological advances permit this to happen without the transmitters interfering with each other (due to different transmission path lengths) thus again improving spectrum efficiency.

3.4.6 The Development of Public Safety Standards

Up until relatively recently, Public Safety systems were being implemented to be the best within the budget that could be afforded, without any common standards of coverage, level of service, reliability, and other key parameters. Over the last five years or so, significant national and international efforts have been put in place to develop generally accepted standards. Due to different operational requirements, specialized standards are in some cases required for Police and Fire Services. It should be noted however that currently (2002) there is very considerable variance in the standards to which Public Safety systems across the country have been implemented.

3.4.7 The Availability of Specialized User Terminals

The actual radio sets used by Public Safety and Public Service officers are of two categories: mobile and portable. Mobile radios are those installed permanently in vehicles such as fire trucks and police cars, while portables are those carried around by the officers themselves.

Until recently, the portable units available have not included specialized functionality for the given Public Safety service, although there has always been a range of units available from inexpensive to high-end. Now greater consideration is being given to the user applications, particularly for high end portables. Thus high-end Police portables will be capable of encryption and are very rugged. High-end Fire Service portables are rugged, water resistant and have the capability of analogue simplex operation which is frequently required in smoke-filled buildings. Due to their lower power and receiver sensitivity, the coverage for portables in any given system is less than that for mobiles.

3.4.8 Summary of Technologies

Given below is a brief summary of the key elements of each of these technologies.

Analogue/Digital

- **Analogue:** proven technology; ensures full interoperability; voice quality variable in problem areas but graceful degradation at the edge of coverage area; lack of security.

- **Digital:** high level of security; superior voice quality but sharp degradation at the edge of coverage; capable of voice and data on one channel.

Conventional/Trunked

- **Conventional: Dedicated channel**
  - Perceived advantage: privacy
  - Disadvantages: difficult access; inefficient channel utilization

- **Trunked: Dynamic channel allocation**
  - Advantages: maintains privacy; pool of available channels; access on demand or with minimal delay.

Trunked Advantages

- Faster system access and transparency to the user
- User priority levels may be established
- Better spectrum efficiency – all channels are shared by all users to reduce channel congestion
- More user privacy – users in the same talk group are given exclusive use of a voice channel for the duration of the conversation
- Flexible expansion – talk groups can be added as can additional channels
- Smooth migration path to future technologies
- Higher system reliability through fail-soft operation

Simulcast/Multicast

- **Simulcast:** the use of multiple transmitters keyed simultaneously at separate sites that share a common frequency.
- **Multicast:** the use of multiple overlapping sites that use different frequencies.

Public Safety Standards

- APCO 25
- Trunking standard
- Narrowband equipment standard
- TETRA – European Trunked Radio Access Standard; TDMA 4-time slots/ch.

The Two Major Types of Design Approach

- M/A-COM
- Motorola

It is important to note that these two systems are incompatible with each other due to the difference in their design approach, in particular the trunking protocols used. Thus, the accepted proviso is that such systems – even in adjacent jurisdictions with common coverage – cannot communicate with each other.

3.5 A Broad Overview of Public Safety and Public Service Networks

Public Safety and Public Service networks are those licensed by and controlled by any of the four levels of government: federal, provincial, regional, and municipal. There are currently no federal Public Safety or Public Service networks to our knowledge. However, the Royal Canadian Mounted Police (RCMP), a federal agency, currently has a number of provincial networks and is actively investigating the coordination of these networks.

Most provincial governments have wide-area mobile communications services, either used by a specific provincial entity or shared by two or more provincial services, typically including one or more Public Safety services. Regional jurisdictions, typified by the Capital Regional District of B.C. and, until recently, the Regional Municipality of Ottawa-Carleton, also control mobile radio communications networks, frequently on a shared basis with various Public Safety and Public Service organizations. However, regional networks are not particularly common.

The vast majority of Public Safety and Public Service networks are municipal networks. Until the last decade, these were almost invariably separate networks for specific municipal organizations such as Police, Fire, Ambulance, Public Works, Transit, and municipal Utilities. There was thus poor use of the spectrum, as each of these required different frequencies and there was considerable redundancy resulting in poor cost effectiveness. The major reason for these individual networks within a single municipality was a technical and operational one – at the time, techniques were not sufficiently developed to permit operationally effective sharing of networks. As discussed in Section 3.4 above, such sharing without the other users being aware of

the other sharees is now available (trunked networks) and is being exploited on an ever-increasing basis.

These municipal networks vary greatly in size, sophistication, number of users, and functions provided (e.g. encryption, interoperability, service specific standards and needs such as those required for Fire Services and a variety of other parameters). To place this variation into context, it is perhaps worth noting that at one end of the scale there are thousands of volunteer Fire Services whose communications consist of voice message pagers and perhaps one or two portable handsets. In the middle of the scale there are the larger municipalities and cities, including those recently amalgamated, typified by Ottawa, Edmonton, Regina, Kingston, and Kawartha Lakes and usually with between 100 user radios (for small unshared networks) to around a 1,000 user radios for the larger shared systems. At the upper end of the range are the larger municipalities such as Metropolitan Toronto, the new City of Montreal, and Vancouver. These very large networks, typically having some thousands of users, are shared between a variety of Public Safety and Public Service entities.

As well as these major variations in size, a key element affecting the use of Public Safety and Public Service networks in a coordinated manner in a natural hazard situation is that of incompatibility between the design approaches used by the two major suppliers of Public Safety and Public Service systems used in Canada (Motorola and M/A-COM).

In our investigations we have found current systems that vary in age from an obsolete thirty-year-old system for which spares are no longer available and *cannibalism* is necessary, to a modern state-of-the-art shared trunked radio system using simulcast technology. It is perhaps worth noting that both of these examples, while tending to be extreme, currently exist in Canadian cities of significant size. Other cities, townships and municipalities have Public Safety and Public Service radio networks spread between these extremes.

Budgets for Public Safety and Public Service networks also vary significantly. It should be recognized that a radio network for Public Safety or Public Service is a tool for these services and one of very many items that a city council must consider in preparing its budgets. A modern municipal radio system will cost between approximately $750,000 to about $25 million and upwards based upon size and complexity; the cost is considerably more for a province-wide system. Thus, in any jurisdiction, these costs are significant and require considerable debate on the part of the municipal or regional council. One impact of this is that radio systems are only replaced or upgraded after comparatively long intervals, typically between ten and fifteen years, but in most cases longer.

Typical drivers for such upgrading or replacement are significant changes in technology, such as the availability of digital systems and the need of Police Services for encryption, trunking systems with their operational and economic advantages, and at the other end of the scale, inability to obtain spare parts due to obsolescence.

Given that there is no coordinating mechanism related to Public Safety and Public Service mobile communications systems, either nationally or provincially, we have found during our

work that there is a huge range across the country of all of the economic, operational, and technical parameters affecting these networks.

An additional variable that should be mentioned is that of control and ownership. Some provinces, such as Nova Scotia and Ontario,[5] have agreements with their provincial telecommunications organizations (Maritime Telephone & Telecommunications and Bell Canada respectively) to implement province-wide Public Service and Public Safety networks to standards defined by the province. However, the majority of networks are owned and controlled either by an individual service such as Police, Fire, Emergency Medical Service (EMS), by Public Works, or by the Municipality where the system is shared. A further factor to be considered is that some jurisdictions prefer to own their radio system infrastructure and user radios, while some prefer to lease these from the suppliers. A final matter regarding control is that Police Services (and thus their mobile radio systems) are controlled by Provincial or Municipal Police Commissioners and are at arms length from the local council except for funding.

3.6 Public Safety System Vulnerability to Natural Hazards[6]

The manner in which Public Safety and Public Service networks address their vulnerability to natural hazards is as variable as the networks themselves. Provincial organizations, typified by the Province of Nova Scotia, tend to include natural hazards with man-made hazards and take these risks and threats seriously with in-place mechanisms for identifying and mitigating them. In areas where the potential for earthquakes has a high profile, such as cities in Western B.C., the newer major Public Safety networks have mitigation techniques against this natural hazard as part of their specifications. These include, for example, the minimizing or elimination of wireline connections between transmitters, switches and dispatch centres, together with the housing of critical switches in buildings designed to earthquake resistant standards. It is important to stress that all of the above examples refer to currently operational networks or those in final design phases (such as the Capital Regional District CREST). They also reflect the higher level of awareness among some Public Safety officials of the potential hazards that may impact on their radio communications and consequently on their operations.

Very little improvement can be made to aging networks, but it is extremely important to encourage Public Safety agencies who are replacing their existing networks to select systems that not only fulfill their operational requirements, but that also take into account natural hazards. They should also provide as much redundancy as possible such as back-up facilities (dispatch centres, infrastructure, and power) and appropriate backhaul facilities.

However, possibly due to the low profile of natural hazards in most parts of Canada and to budget constraints, we have found that, in the large majority of systems, little or nothing is done to identify or mitigate natural hazard vulnerabilities. Unfortunately, it is also true to say that the vulnerability of Public Safety telecommunications networks to natural hazards does not occupy a high priority with most of their users and managers.

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[5] See Bibliography, Item 39.
[6] See Bibliography, Item 46.

3.7 A Broad Overview of Public (Cellular and PCS) Mobile Networks

Public mobile networks are those owned and controlled by commercial licensees and available to any member of the public who pays the user fee and obtains an appropriate user terminal. It is perhaps necessary to commence this section by identifying the difference between cellular and PCS systems. Cellular systems are analogue or digital systems operated by one of the two licensed cellular service providers, Rogers AT&T, and the traditional telephone companies. They operate in the 800 MHz band. The latter are currently in two major competitive groups, those of Bell Mobility and its affiliates and those of Telus Mobility and its affiliates.

A brief review of the historical background of cellular and PCS systems is perhaps appropriate. In 1987[7] what was then Rogers Cantel was awarded a license to provide analogue cellular service on a nation-wide basis (digital systems were not available at that time). Federally incorporated and provincial traditional telephone companies wished to provide similar service in their own jurisdictions. This was permitted by the CRTC after a holding period of approximately six months to allow Rogers Cantel to commence implementing their service. For approximately ten years this duopoly served the country well with both groups of service providers competing to provide ever increasing coverage and quality of cellular service. With some modifiers such as digital cellular systems this situation still applies for cellular service.

A cellular system is based upon the concept of greatly increasing spectrum efficiency by combining wireless and computer techniques to provide to the public multi-channel service of limited power and very high frequency re-use. Thus, a cell of frequency coverage is established using a control channel and a significant number of other channels to provide general Public Service. Whenever a user's cell phone is on, it is constantly accessing the control channel to see if there is a call for it, or if a channel is available if it wishes to transmit. In either of these circumstances, the call – either incoming or outgoing – is immediately transferred to an available channel of the group of frequency being used, in a manner very similar to trunking technology.

If a user moves toward the boundary of the limited coverage of the cell, the call is automatically and transparently *handed over* to the next cell that uses a different group of frequencies. As it moves out of this cell, for example in a straight line, it would be handed over to a third cell, which could well use the same frequency group as the first cell. By this method very large numbers of public wireless users can be accommodated throughout the country with a comparatively small number of frequencies. It was the lack of a sufficient number of public mobile radio frequencies that, prior to the advent of cellular service, had greatly inhibited the use of public mobile radio service[8].

In the mid 1990s Industry Canada made new spectrum available in the 1900 MHz band for a similar service designated the Personal Communications System (PCS) which made even more efficient use of the spectrum by being restricted to digital systems, which use far less spectrum per channel. From the viewpoint of the user, the two services are essentially transparent with any public mobile phone being termed a *cell phone* whether it uses cellular or PCS service. A further *blurring of the boundaries* has occurred as both Bell Canada and Telus use the 800 MHz band to

[7] See Bibliography, Item 53.
[8] See Bibliography, Item 54.

provide digital service. Virtually all cell phones will automatically revert to analogue operation when the user moves out of the comparatively limited coverage of digital service.

The new PCS licenses of the mid 1990s were awarded to Clearnet of Toronto (now part of Telus) and Microcell of Montreal, with additional, but more limited, spectrum being licensed to Rogers AT&T and the traditional telephone companies. For the remainder of this section the term cell phone or cellular coverage will be used for both cellular and PCS service. However, digital and analogue service will be differentiated.

Over the approximately 15 years that cellular service has been available, both its coverage and its use have grown very significantly. Cellular service is now available coast to coast in all major cities, many smaller cities, and along most major transportation corridors. Within the context of overall coverage, digital service is comparatively limited, with its advantages being gained primarily in high population density and high spectrum congestion areas.

In considering public mobile radio systems, it is important to recognize that although all four service suppliers (Rogers AT&T, Microcell, Telus, and Bell Canada Mobility) each show a very considerable coverage, the networks of Microcell and that portion of Telus previously owned by Clearnet only cover digital service. All other portions of their coverage maps relate to analogue coverage that is provided under various agreements with Rogers AT&T and the mobile radio organizations of the traditional telecommunications carriers. Thus, the maps can be very misleading and should not be taken to mean that each of the four cellular licensees themselves have all of the coverage shown in the coverage maps.

It should also be noted that the services of the four different service providers are incompatible with each other as they use different technical systems. However, all calls are routed through the Public Switched Telephone Network (PSTN) and then to the person being called. The PTSN may have an ordinary telephone or a cell phone on any system. An overview of the cellular and PCS systems currently licensed in Canada is provided in Figure 3.

Figure 3 National and Semi-National Public Cellular and PCS Carriers
(Source: Anderson & Gow, 2000)

• Bell Mobility (cellular 800 MHz – AMPS; 1.9 GHz – CDMA digital) – Coverage in Ontario and Québec; B.C. and Alberta (through a reselling agreement with Telus Mobility)
• Telus Mobility/Clearnet – B.C., Alberta (Clearnet also covers Ontario and Québec); Telus Mobility (through a reselling agreement with Bell Mobility for Ontario and Québec)
• Rogers AT&T (cellular 800 MHz – AMPS; 1.9 GHz – TDMA digital) – national coverage
• Microcell (1.9 GHz – GSM) – Québec, Ontario, Alberta, B.C.
• Globalstar Canada (a satellite service provider)
• TMI MSAT (a satellite service provider)

3.8 Cellular and PCS Vulnerability Factors

In general, our findings indicate that cellular and PCS networks lack the following requirements that are usually necessary for Public Safety systems:

- Priority access;
- Avoidance of network congestion; and
- Public Safety coverage and connectivity criteria.

The lack of these attributes in a cellular system will limit the use of these networks in the response and recovery phases of a disaster.

As the loading of public networks is ultimately decided by the end user, the public itself, the *Public Safety* control of the loading of these networks in a natural disaster is very difficult to implement. Historical accounts of commercial telecommunications network survivability are difficult to find and very rarely analyzed. However, the following is a quote from Peter S. Anderson and Gordon Gow from the Centre for Policy Research on Science and Technology at Simon Fraser University in Vancouver, B.C.[9]:

> *Despite the promise of this emerging technology, the specific benefits, limitations and ultimate implications of emergency cellular/PCS usage are not yet well understood by the emergency management community, policy makers or, for that matter, by all service providers. Virtually no Canadian or international research has been undertaken to document and examine issues and solutions for operation of such facilities under emergency or disaster conditions, especially when such facilities themselves are impacted by the same hazard event.*

Generally, Public Safety or emergency management agencies do not rely on Public networks in a crisis. However, there have been exceptions, (i.e. the Ice Storm of 1998 where, due to major failures of landlines, these networks offered an alternative during that prolonged crisis). Due to the large number of cells deployed, these networks were able to survive better than some landlines. However, our research has not yet identified any Emergency Preparedness agency that would be fully relying on public wireless networks, and such use is not expected in the near future.

3.9 Paging Services

It is often unrecognized that paging networks play an important, and possibly critical role in Public Safety activities. Numerically, the largest numbers of Public Safety organizations in Canada are those of the volunteer Fire Services that serve not only the smaller municipalities and Canada's vast remote areas where they are on call for forest fires, but also provide, in part, the Fire Services' response for larger cities such as the *New* City of Ottawa.[10] These volunteer firemen are called to duty by means of pagers, from a dispatch point that is often located in the homes of a small number of volunteer dispatchers providing their services on a shift basis.

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[9] See Bibliography, Item 11.
[10] See Bibliography, Item 36.

Paging services are also used by both Police and the Emergency Medical Services (EMS), but to a lesser extent than by the Fire Services. In some municipalities, the Public Service organizations such as Public Works, Transit, and Fleet Management also use paging systems. Some of the paging systems, particularly those used by the Fire Services, are simple private systems often using the Fire Marshals' or Mutual Aid frequency. There are also a large number of public paging services, ranging from those providing local service in a small town to those providing national coverage. Again there is no commonality or coordination regarding the use of paging services. The particular type of paging service used and the frequency of its use is determined on an operational basis by the individual municipality or other jurisdiction.

4.0 Impact of natural risks on telecommunications networks in Canada

According to national policy, Canada is to become one of the *most connected* countries in the world. This of course refers to telecommunications access and connectivity, and includes mobile and telecommunications services as well as Internet and wireline services. Canada is fortunate in this respect having:

- Wide-area Public Safety and Public Service telecommunications networks in most of our provinces;
- State-of-the-art and competitive cellular services with coverage in the populated areas;
- Excellent fibre optic trunked wireline services with competition throughout Canada; and
- Excellent paging services.

Given all of these telecommunications advantages, it is unfortunate that disaster recovery in Canada must often rely upon the facilities and abilities of *in place* municipal Public Safety systems that have widely varying capabilities and standards. This paper attempts to identify these variables and their impact on network vulnerability to natural hazards. For example, poor mobile communications interoperability between the various Public Safety and Public Service organizations involved is of particular concern.

4.1 Natural Hazards and Disasters in Canada

Canadians are exposed to a variety of natural hazards depending on where they live. In general, Canadians have been very fortunate to experience a relatively low incident rate and severity of natural disasters compared with, for example, the United States. However, based on historical facts and scientific research it is known that Canada will continue to face the threat of natural disasters, some more considerable than those experienced in the past. As shown in Figure 4, in the past two decades the following Canadian natural disasters caused the most damage and in many cases human loss.[11]

[11] See Bibliography, Item 45.

Figure 4 Major Canadian Natural Disasters: 1985 – 2000
(Source: Janet Looker, Disaster Canada, Lynx Images Inc,. 2000)

1985 – Barrie, Ontario; **Tornado** – 12 deaths
1987 – Edmonton, Alberta; **Tornado** – 26 deaths
1991, 1992 – Calgary, Alberta; **Hailstorms** – no human loss
1996 – Saguenay, Québec; **Floods** – 10 deaths
1997 – Winnipeg, Manitoba; **Red River Flood** – no human loss
1998 – Eastern Ontario, Québec and Maritimes; **Ice Storm** – 28 deaths
1999 – Kangiqsualujjuaq, Québec; **Northern Québec Avalanche** – 9 deaths
2000 – Pine Lake, Alberta; **Tornado** – 11 deaths

These events serve to highlight the significance of natural hazards to Canadians. While many hazards are regional, some events can have widespread impact, and have the potential to disrupt life on a broad spatial scale. A prime example of a widespread natural disaster was the Ice Storm of 1998. The following map (Figure 5), representing the intensity of Ice Storm '98 and its disastrous consequences on hydro transmission, distribution, and telecommunications network, was provided during hearings conducted with a group of international experts working with Hydro Québec in the aftermath of this disaster. It shows the thickness of ice accumulations in various affected areas greatly exceeded any normally expected conditions and corresponded to an event that would occur once in 500 years. An unprecedented area was affected by this event, from Eastern Ontario, through Québec, to New Brunswick, and into Nova Scotia.

Due to their geographic location, some provinces have historically had higher risk of natural hazards than others. Details on the relative risks due to various natural hazards in different provinces are provided in Section 5.0.

From a financial point of view, some of the most devastating Canadian natural hazards have been floods, severe winter storms and windstorms, droughts, hail, and tornadoes. Potentially earthquakes are also a significant natural hazard. Another factor is that Canada has become increasingly urban. Statistics Canada figures for 2001[12] show that 79.5% of the population now lives in urban areas and their outlying suburbs. Urbanization has increased the potential losses arising from natural hazards because of greater concentrations of people and assets including telecommunications networks. For example, the potential loss of life and cost of an earthquake in Greater Vancouver or Victoria has been rising with population growth.

[12] See Bibliography, Item 35.

Figure 5 Map of Ice Storm '98
(Source: Hydro Quebec, 1998)

4.2 Emergency Management and Mobile Communications Networks

Local, regional, provincial, and federal governments all have Emergency Management Organizations that typically coordinate the planning, response, and recovery aspects of any hazardous event. They work to prevent these events from becoming disasters. Most of the provinces in Canada treat the threat of natural hazards under *all-hazard* emergency plans.

Ideally, in an emergency a Command Centre is very quickly set up and all personnel are issued portable radios that provide interoperability with local Public Safety agencies. Emergency plans include a list of contacts for all essential agencies and organizations (utilities, wireless public telecommunications providers, governmental departments, etc.) to coordinate the response and recovery efforts. Most emergency managers do not have a specific inventory of telecommunications assets in their area. If an emergency arises, they rely on reaching designated contacts to find out the impact of an event on communications links (wireline and wireless) or the local utilities, and get an estimate of the time required to repair any damage.

Most of the provinces in Canada[13] treat the threat of natural hazards under *all-hazard* emergency plans. A brief paragraph on any particular aspect of *all-hazard* emergency plans in a given province is provided within the appropriate section dealing with telecommunications networks in that province. British Columbia[14] is somewhat unique in this regard in as much that it deals with *hazard-specific* emergency plans.

4.3 Current Standards for Public Safety Communication Systems

Standards[15] for Public Safety radio systems have been developed over the years by such organizations as the Association of Public-Safety Communications Officials (APCO), working with the recognized standards development body for telecommunications-related standards, the Telecommunications Industry Association (TIA). Of particular interest are two initiatives of APCO, APCO-16 and APCO-25. APCO-16 is an initiative to develop a trunking standard for radio systems that would meet the specific needs of Public Safety. Currently available trunking systems (e.g. SMARTNET™ and EDACS®) meet this standard.

APCO-25, on the other hand, was an initiative to develop standards for digital radio systems and to meet the Federal Communications Commission (FCC) requirements for *refarming* radio frequency spectrum in the VHF band by reducing the occupied bandwidth (narrowbanding). One element of APCO-25 was the selection of a digital voice coder. This was overwhelmingly successful, resulting in the selection of the IMBE (Improved Multi-Band Exitation) coder, considered to have outstanding performance. This coder is now available from Motorola and M/A–COM.

Under APCO initiative, the Public Safety community has adopted standards for performance of Public Safety radio systems. The main parameters of concern are:[16]

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[13] See Bibliography, Item 60.
[14] See Bibliography, Item 60.
[15] See Bibliography, Item 12.
[16] See Bibliography, Item 12.

- **Area coverage reliability:** Public Safety – 97% (Note: this objective has been stated in some jurisdictions in terms of a 95% probability of an acceptable level for a portable radio worn at hip level.)

- **Delivered Audio Quality (DAQ):** Public Safety – 3.4 (Note: For the IMBE coder, this is equivalent to a 2% Bit-error-rate [BER]).

- **Grade of service (GOS):** The system design shall be such that attempted calls are not lost but are held in a queue. The system shall have sufficient channel capacity to support a traffic GOS such that not more than one (Lowest Priority) call in any one hundred consecutive calls shall be queued for a period exceeding four seconds (proposed at this time).

The responsibility of implementing Public Safety telecommunications networks and standards typically resides with local governments, as does the responsibility of responding to natural disasters. The level of emergency preparedness is directly influenced by financial considerations and the ability to communicate between the various local agencies, i.e. the interoperability of their communications systems. However, the lack of adequate funding at the municipal, regional and, on occasion, at the provincial level, quite often hinders the efforts to offer a Public Safety grade of service on these networks.[17]

Thus, particularly in smaller municipalities, there are still many aging local telecommunications infrastructures serving Public Safety and local governments that are becoming increasingly difficult to maintain, that do not provide interoperability between Public Safety and Public Service agencies and that are lacking redundancy for essential elements of their overall infrastructure. This makes them susceptible to failure under adverse conditions.

In many jurisdictions, the lack of interoperability between Public Safety networks deployed in the same geographical area also represents a major vulnerability of telecommunications to natural (and man-made) hazards. Recently, strides are being made in Canada to build Provincial public service wide-area networks that, with some enhancement, can support Public Safety agencies, thus providing at least interoperability between Public Safety agencies and Public Service departments. The survivability and the interoperability of private telecommunications networks are two main considerations in assessing telecommunications networks performance in any future disaster scenario.

Public mobile telecommunications networks are typically susceptible to similar natural hazards as Public Safety and Public Service networks. The use of public wireless telecommunications networks within the Public Safety sector is still very limited. On a day-to-day basis they are typically used for administrative and non-critical purposes. Generally, Public Safety agencies and emergency managers do not rely on public wireless telecommunications in emergencies. The most frequent reason for disruption of public telecommunications systems (cellular and PCS) in emergencies is the overloading of these systems by the general public immediately following a disaster event.[18] This can be overcome, to a certain extent, by assigning priority access to all

[17] See Bibliography, Item 46.
[18] See Bibliography, Item 11.

facilities used by Public Safety agencies and the local emergency managers (an ongoing process dealt with by major telecommunications associations or various working groups). However, this approach is difficult for private companies both technically and from a regulatory viewpoint.

Generally, wireless common carriers address high-risk zones through upgrade programs and by their own Emergency/Disaster Planning. For example, Telus[19] has undertaken an extensive seismic upgrade program focusing on major equipment buildings in high-risk zones. Most of their buildings containing key switches and other equipment are classed as *post-disaster structures*, meaning that they are likely to survive an earthquake. The buildings' switches, radio equipment and heating, ventilation, and air conditioning support systems (HVAC) are braced for an earthquake, and they have uninterruptible power in the form of generators and batteries. Based on past historical data[20] from recent major earthquakes in other jurisdictions, it is recognized that while switches, towers and lines have generally remained intact, heavy traffic volumes and power outages have posed problems for telecommunications.

The distribution, transport, and telecommunications facilities of hydro companies are at least as susceptible, and probably more so, to natural and other hazards as other telecommunications facilities. As typified by the 1998 Ice Storm,[21] the horizontal loading of the hydro wires can cause a *domino effect* of collapsing hydro pylons. At the 2001 Canadian APCO Conference in Penticton, B.C., the Disaster Preparedness Coordinator for BC Hydro stressed the importance of developing effective emergency (disaster) response capabilities through regular exercises.

4.4 The Vulnerability of Specific Elements of Telecommunications Infrastructures to Natural Hazards

Due to the very large number of telecommunications networks deployed in Canada, their variability and their susceptibility to various types of natural hazards associated with specific geographic locations, it is beyond the scope of this project to assess their vulnerability on a network-by-network basis. Instead, components of the telecommunications infrastructure are identified together with their potential vulnerability to natural hazards on the basis of known engineering practices. This information will permit emergency managers to make a reasonable assessment of vulnerability on a case-by-case basis. It is therefore essential that all emergency managers be aware of the various components of a telecommunications infrastructure they rely on and on their survivability in a disaster scenario in order to assess vulnerability of their local surroundings.

The main components of a telecommunications infrastructure are:

- Physical buildings
- Power supply
- Transmission Links
- Telecommunications Towers
- Antennas

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[19] See Bibliography, Item 47.
[20] See Bibliography, Item 11.
[21] See Bibliography, Item 48.

Given below are the primary vulnerabilities of each main component including, where available, information on how these vulnerabilities can be mitigated or overcome.

4.4.1 Physical Buildings

Physical buildings used in telecommunications networks typically house the following:

- Switching equipment, controllers, and other radio equipment
- Dispatch facilities of first responders
- Antennas (roofs of buildings are often leased for the deployment of antennas)

As with most physical structures, the ability of a building to withstand a natural disaster is influenced by age, type of construction, materials used, and type of hazard. In the engineering design of buildings, environmental loads (i.e., extreme snow loads, wind loads), and temperature effects govern many parameters. Engineers designing structures are accustomed to allowing for these climatic effects by using *design* values prescribed by code-writing bodies. The environmental loads are often most significant when they act in combination. Wind, for example, acts frequently with waves, blowing snow, rain, or hail.

The National Research Council of Canada (NRC) conducts research on buildings and makes recommendations for inclusion in both the National Building Code of Canada (NBCC) and the National Fire Safety Code (the latest issue of each is 1995). However, as construction standards rest with the provinces, municipal enforcement of these standards is said (anecdotally) to be uneven.

Many buildings were erected when knowledge of natural hazards, and of earthquakes in particular, was in its infancy. Consequently, many of Canada's private buildings, as well as the public infrastructure, fail to meet current standards for structural integrity identified in the National Building Code. Although in British Columbia, buildings constructed since 1985 have been designed to withstand such shaking resulting from predicted earthquake intensities, it is estimated that only half of British Columbia's buildings constructed between 1960 and 1985 can withstand shaking, and those erected before 1941 have little or no earthquake tolerance. Furthermore, while the NRC provides guidelines for evaluating buildings for seismic resistance, there are no guidelines for retrofitting.

National Building Code

The code has included provisions for earthquake-resistant design and construction of buildings since its first edition in 1941. The seismic provisions of the code's early editions were based on the United States building code. The seismic zoning map in the 1970 edition was the first to present probability estimates of seismic ground motion for the whole of Canada. The 1995 and previous codes do not consider a subduction earthquake. We understand, however, that the impact of subduction earthquakes is likely to be recognized in changes to the seismic content of the National Building Code in the next issue (expected in 2003).

Theoretically, communities that are near the epicentre of such an earthquake could suffer considerable collapse and damage to infrastructure, even if that infrastructure was built to the

most recent seismic code. However, current calculations suggest that the design level of ground motion included in the present code is equal to, or greater than, the ground motion that most *British Columbian* communities in the high hazard areas would experience in a subduction earthquake. Although there are a relatively small number of communities at risk, it seems appropriate for the provincial government to ensure that these communities have access to whatever advice and technical support they may seek for making local modifications to the national code.

Another important point is that the seismic safety component contained in Part 4 of the provincial code[22] does not apply to all structures. Bridges, roads, water and gas pipelines, and transmission towers are not within the scope of the code. Moreover, the construction of buildings of fewer than three storeys and of an area less than 600 square metres (which includes many fire halls, ambulance and police stations) are governed by Part 9 of the provincial code which does not contain a seismic safety component. However, in some cases such as bridges, other standards govern how they are built. But in cases where no specific standards apply, it is up to the owners or developers of these infrastructures to set the design criteria. Many do design to a similar seismic standard as given in the national code, but it seems to be at their own discretion.

It should also be pointed out that, under the *Municipal Act*, the B.C. provincial government is not bound by any enactment that would bind or affect it in constructing improvements on lands that it owns. Improvements for this purpose include buildings and structures. The Provincial Building Code is a minimum standard only. Each community is responsible for ensuring that the code is amended where necessary to reflect conditions within its boundaries.

Earthquakes, hurricanes, floods, and tornadoes have traditionally had the most impact on structural design and have influenced changes to building codes (usually within two years of a major natural disaster). Various other mitigation strategies have been established following other natural disasters over the past couple of decades, such as wild land fires, extreme heat, or wind/hail storms.

4.4.2 Power Supply

Local records of a number of telecommunications systems show that the greatest single cause of system *outage* is the loss of primary electrical power. This can affect any of the active components of the infrastructure. Most of the physical buildings housing switching or RF equipment, as well as dispatch centres, will have redundant sources of power, Uninterruptible Power Supplies (UPS), batteries and generators. However, a prolonged hydro power outage may lead to generators being overloaded or running out of fuel and to batteries exhausting their capacity, and an inability to access the site can significantly limit the use of portable generators during a natural disaster.

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[22] See Bibliography, Item 49.

4.4.3 Transmission Links

There are four main types of transmission links used in telecommunication networks. They are:

- Landlines (Coaxial and Copper)
- Fibre optic
- Microwave
- UHF

In earthquake prone zones the use of a microwave backbone is the preferred means of transmission link[23] as it mitigates the danger of breaks in landlines along highways, bridges, or in a downtown core (except for possible misalignment of microwave antennas at tower sites after an earthquake). Redundant landlines or *self-healing fibre rings* as mitigation means to maintaining telecommunications networks functional in a post-disaster scenario are also extremely important to any network. However, landlines (with the exception of fibre links) are also susceptible to water damage.

4.4.4 Telecommunications Towers[24]

There are two types of telecommunications towers:

- Self supporting tower
- Guyed tower

All telecommunications towers are being designed to the Canadian Standard S37-1 that deals with wind and ice loading using one in 50 years occurrence factors. The location of a telecommunications tower within the different loading zones as defined by wind load and ice load maps determines the tower design.

Regional ice loading specifications:

- B.C. – 25 mm ice loading around the members
- Prairies to parts of Northern Ontario – 10 mm
- Ontario and far north and as far as Montréal – 25 mm
- From Montréal to Québec City, Labrador and Southern Nova Scotia – 40 mm
- Northern Nova Scotia, P.E.I. and Newfoundland – 50 mm

Some areas in Northern B.C. that would typically experience heavier ice load would have their own local requirements for tower design standards.

Wind Loading

The wind load map in the building codes is apparently very conservative (based on wind speed), and structural engineers designing telecommunications towers prefer not to use it. Instead, they

[23] See Bibliography, Item 46.
[24] See Bibliography, Item 50.

are designing the towers for wind pressure (converting wind speed to wind pressure using a constant established for Canada).

There are three regions of wind loading uncertainty in Canada that are not amenable to the use of standard curves. These are:

- B.C. mountains
- Great Lakes
- Newfoundland

To determine the appropriate requirements for a location within these regions, Environment Canada supplies specific data on a particular location. The mathematics of wind loading on a tower show that the self-weight of a tower is not a factor in the vulnerability of these structures. In earthquake hazard zones, consideration may be given to strengthening the foundation. In all cases, a safety factor is built into the tower design by multiplying the calculated wind loading by 50% so typically towers will withstand wind and ice loading equal to a one in 100 years occurrence.

4.4.5 Antennas[25]

In hurricane prone areas, antennas can be one of the weakest links in the telecommunications infrastructure. The antenna design is thus of the utmost importance. In winds of 140 km/h, towers typically survive but antennas may be lost, or, in a worst case scenario, the top portion of the tower may be lost. In ice storms, parabolic antennas can add to the wind load on the towers as the surface of antennas increases due to the amount of icing. In critical cases, this can be mitigated by adding a flexible ray dome to shed the ice in wind storms, or by heated ray domes.

5.0 The Mobile Radio Systems of Each Province/Territory and Their Vulnerabilities

The concentration of mobile communications networks across Canada corresponds roughly to the population density. Consequently, the most populated areas in Canada are also those of heavy spectrum congestion. They are also likely to be the most vulnerable to mobile radio system disruption during a natural disaster. The highest population concentration areas are Calgary, Edmonton, Montréal, Toronto and Southwestern Ontario, Vancouver, and Victoria.

As mentioned previously, current wireless mobile telecommunications networks can be divided into two main categories: private and public. In this section we give a brief summary of natural hazards specific to each province, the key telecommunications networks used by their Public Safety agencies and local or provincial governments (private networks), the public networks in the province, and the vulnerability of each type of network. It will be noted that the amount of information available on each province varies very considerably. In general, this reflects the provincial differences in population, density of existing private networks, and the information that can be obtained through knowledgeable contacts.

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[25] See Bibliography Item 51

The data presented here in text format is also included in all databases but is formulated in a sortable manner (Appendix B). Given that the systems of the two major suppliers are incompatible and thus represent a potential vulnerability, the supplier name has been printed in **bold** for each network for ease of identification. In many cases in this section the term "site" is used without further qualification. In all cases this refers to the location of an antenna. Typically these will be on a tower or a rooftop. They are usually concurrently transmit and receive antennas but are, on occasion, receive-only antennas. Information on these categories for individual sites is generally not available.

Please also note that much of the information given in this section was obtained from individual phone calls or face-to-face interviews.

As mentioned in Section 2.0, an estimate of the vulnerability of the network can be carried out using the information available in the databases. Key parameters in estimating the vulnerability of the network include:

- System age (less than four years has minimal impact while more than 10 years has maximum impact);
- A digital system as compared with an analogue system (likely to be less vulnerable to interface and coverage problems);
- A trunked system (will provide interoperability within a service by the use of talk groups where it is unlikely that a conventional system will);
- A shared system (will provide interoperability between services).

These vulnerability mitigation factors, particularly when combined with local knowledge of the main components of the individual telecommunications infrastructure (see Section 4.4 of the report), will permit a vulnerability estimate to be made of a given system.

5.1 British Columbia

5.1.1 Natural Hazards[26]

As shown in Figure 6, British Columbia, due to its geology, is a high-risk natural hazard zone. Every year major and minor floods are reported throughout the province. British Columbia is also the province with the highest incidence of forest fires in Canada. Landslides occur frequently. Pacific-wide tsunamis and regional tsunamis can threaten the B.C. coast. The threat of a major earthquake possibly generating local source tsunami or a volcanic eruption in this province and affecting heavily populated areas of the Lower Mainland and Vancouver Island is also a serious concern.

[26] See Bibliography, Item 55.

Figure 6 Natural Hazards Occurring in B.C.
(Source: B.C. Earthquake Response Plan, 1999 Edition)

- **Forest Fires** – During an average year there are approximately 2,900 forest fires in British Columbia affecting 30,000 hectares of provincial forests and rural community areas at a cost of $90 million.
- **Earthquakes** – At least once a week an earthquake of sufficient magnitude to be noticeable occurs somewhere in the province. Severe earthquakes capable of causing serious damage in coastal areas occur every 25 to 40 years.
- It is predicted by geologists that a major earthquake resulting in widespread damage to southwestern British Columbia occurs every 300 to 500 years.
- **Floods** – During the year 2000 there were 202 major and minor floods reported throughout the province with $55.4 million allocated to provide financial assistance to flood victims.
- B.C. is also vulnerable to tsunamis, landslides and volcanic eruptions.

At least once a week an earthquake of sufficient magnitude to be noticeable occurs somewhere in the province. Severe earthquakes capable of causing serious damage in coastal areas occur every 25 to 40 years. A major earthquake resulting in widespread damage to Southwestern British Columbia is expected to occur every 300 to 500 years.

5.1.2 Private Mobile Communications Networks

Provincial Networks

The Ministry of Forests deploys the largest network in B.C., covering about 80% of the province and has 40 district offices.

The Protection Branch of the Ministry of Forests and their Centre of Operations are located in Victoria on Jutland Street. The Operations Centre coordinates the operations of Fire Centres in the Province of B.C. and the deployment of fire fighting assets (personnel and equipment) using not only traditional voice communications but also state-of-the-art technologies such as tracking of aircraft and satellite facilities. Globalstar™ satellite fixed phones are used in Fire Camps (60-70 units), and each Fire Centre has an allotment of Globalstar™ handheld phones. However, Globalstar is now in receivership.

The Ministry of Forests, analogue VHF radio communications network consists of 325 sites (18 sites are equipped with *air net* repeaters operating on simplex 164.4 MHz for the management of forest fighting airtankers). All Ministry of Forests repeaters have been tested to -40°C. Frequencies used are in the 163 and 164 MHz range and two to six channels provide radio

backhaul. In total, there are six dispatch centres throughout B.C. The user equipment numbers are between 6000 and 7000 mobiles, and portables for about 3000 employees. Out of the 325 communications mountain-top tower sites, 70–80% are solar-powered (capable of four months operation even under cloudy conditions).

The B.C. Ministry of Forests is exploring the possibility of implementing a new network that would be shared between all ministries and other province-wide agencies (Ministry of Highways, Environment, Agriculture, Health, Sheriffs, Courts, RCMP, PEP, etc.). The current cost estimate for this shared governmental network is approximately C$1.5 billion.

The RCMP and B.C. Ambulance operate their own private networks. They are also users of the new E-Comm Radio Network and will be using the new CREST network in Victoria once it has been implemented. The Coast Guard also has an extensive radio network along the B.C. Coast.

Regional Networks

a) Capital Regional District of B.C.

The Capital Regional District of B.C. is in the process of refining the architectural design of the new Capital Regional Emergency Services Telecommunications (CREST) network. The new network will serve the existing 47 Public Safety and Public Service stakeholders (including small volunteer fire departments) who are currently operating a number of radio networks that typically do not interconnect with each other. The new CREST network, similarly to the E-Comm network, will be using modern technologies and implementing all available mitigation measures to minimize the vulnerability to an earthquake hazard.

Further details are provided in the case study in Section 6.3.

b) Greater Vancouver Regional District (GVRD)

E-Comm Operations Centre and Radio Network are owned and operated by E-Comm Corporation (consisting of a Board of Directors, User Committees, a General Manager and corporation employees). The governance agency is a Corporation created under the B.C. *Company Act*, tailored through provincial legislation for the specific role it carries out.

The E-Comm Radio Network is considered to be one of the most advanced emergency communications systems in the country. The Area Wide Radio system covers approximately 33 668 sq. km (13 000 sq. Mi.), from Boston Bar to Pemberton to Sechelt to the U.S. border. It provides service to over half the population of British Columbia and includes features not present in existing radio systems, as well as providing a high degree of security through post-disaster construction and redundancy.

The unique type of ownership, the approach to satisfying the individual needs of each Public Safety agency reflected in the network design, the accommodation of unified emergency management in a state-of-the-art self-supporting Emergency Communications Centre, and the implementation of mitigation measures to withstand an earthquake represent a new approach to dealing with potential natural hazards.

Notwithstanding this and the fact it was implemented three years ago, it is still on its *learning curve* of management, functionality, and operational approaches. Some of its key parameters are the following:

- Designed to support all of the Lower Mainland Public Safety and municipal services under normal and disaster conditions
- Accommodates growth through to year 2002
- Includes between 60 and 70 receive sites, 25 of which are in the GVRD
- Has up to 143 – 800 MHz frequency pairs available

5.1.3 Public Mobile Communications Networks

The following public networks are operational in B.C.:

- Telus Mobility (analogue, 800 MHz and 1.9 GHZ PCS + paging)
- Rogers AT&T (cellular 800 MHz – AMPS; 1.9 GHz – TDMA digital + paging)
- Microcell (1.9 GHz – GSM)
- Globalstar Canada

Telus also has an extensive Mike™ (a public dispatch-based system) network in Peace River serving commercial customers. In the interior of B.C., Omega Communications Ltd. owns a paging network with centres in Kelowna, Kamloops and Penticton.

5.1.4 Vulnerability

GVRD and CRD have the heaviest population concentration as well as the heaviest concentration of telecommunications networks in B.C. The new telecommunications infrastructures (E-Comm Centre and Radio Network and the new CREST network) as well as Telus facilities have, or will be implementing, all available mitigation measures to minimize their vulnerabilities to an earthquake. The next major step in the overall emergency preparedness is the coordination of the response to a major natural disaster, a clear identification of responsibilities including those relating to the declaration of a disaster and training exercises to identify the strengths and weaknesses of human resources, and testing the capabilities of telecommunications resources.

In the meantime, the currently used communications facilities of a large number of Public Safety networks in Victoria and surrounding municipalities represent a major vulnerability, mainly due to their older infrastructure and the lack of interoperability. This situation would, at the present time, severely hinder the flexibility of response and response coordination. The implementation of the new CREST network, starting in 2002, is expected to go a long way to improving emergency response capabilities in the event of a major disaster.

The potential province-wide upgrade of aging government networks, or the implementation of a new private telecommunications network serving all ministries, would also contribute to better survivability of telecommunications facilities in an earthquake scenario.

5.2 Alberta

5.2.1 Natural Hazards

Two major tornadoes have struck locations in Alberta in the past 15 years causing significant material damage. In addition, blizzards, and hailstorms are very common. The high plains immediately east of the Rocky Mountains experience the most frequent hailstorms in North America. This so-called *Hail Alley* extends southeast from northern Alberta, into Montana, U.S.A. There is an average of nine or ten hailstorms per season. Some locations in the higher elevations of the Rockies may experience 20 or more hailstorms annually.

Canada's most costly natural disaster of this type occurred in Calgary on 7 September 1991. A severe hailstorm struck the city causing $342 million damage to homes, businesses, and automobiles. Another 40 major hailstorms strike the province every summer. Over the past decade, these hailstorms have caused $1 billion damage in Alberta.

5.2.2 Private Mobile Communications Networks

a) The Government of Alberta

The Government of Alberta, through Telus, operates an analogue thin route province-wide Multi-Departmental Mobile Radio System (MDMRS) in the 450 MHz band, built for Telus by Tait. The network covers most of Alberta.

b) The RCMP

The RCMP is still operating a Province of Alberta Communications (PAC) system implemented in the late 1980s.

c) Municipalities of Alberta

City of Calgary

The Calgary Police, Fire and Ambulance Services operate a 6-site, multicast **Motorola** SmartZone™ network that was implemented in 1997.

City of Edmonton[27]

The City of Edmonton has a shared Public Safety digital trunked radio system (with analogue capability) which was implemented in 1995. The **M/A-COM** EDACS® system has 16 channels, with 4-site simulcast operation. All channels are capable of analogue or digital communications. It is compliant to the APCO-16 Public Safety standard.

The user groups of the system are:

- Edmonton Police Service (EPS)
- Edmonton Emergency Response Department (ERD)
- Bylaw services

[27] See Bibliography, Item 56.

There are also other radios on the system that has been provided to key partners (i.e. Capital Health Authority – Emergency Rooms). EPS plans a transition to all digital and encrypted radios during 2002.

5.2.3 Public Mobile Communications Networks

Alberta is served by the following cellular networks:

- Telus Mobility
- Rogers AT&T Wireless
- Microcell

These systems cover Edmonton and Calgary together with a major highway between them in addition to the Trans-Canada Highway. The main Network Switching facility for Telus is located in Alberta.

5.2.4 Vulnerability

The major cities – Edmonton and Calgary – each operate modern, shared digital simulcast systems. This in itself provides a significant level of mitigation in the event of tornadoes and hailstorms that are the major natural hazards in Alberta. On the other hand, both the Government of Alberta and the RCMP systems are old and, from the information available, do not have the advantages of modern systems. However, they are both province-wide systems primarily operating in areas of low population and thus the risk of tornado and hail damage is likely to be low.

5.3 Saskatchewan

5.3.1 Natural Hazards

Saskatchewan is prone to severe winter storms (blizzards), hailstorms, flooding, to localized hazards such as tornadoes and, in the North, to forest fires. The Canada Report 2000 by the CIFFC indicates that there are on average 728 forest fires per year in Saskatchewan.

5.3.2 Private Mobile Communications Networks

a) Municipalities of Saskatchewan

Saskatoon

The Saskatoon Police Department has within the last two years implemented a fully digital **Motorola** ASTRO® APCO-25 fully compliant trunked radio system that provides the latest in technology advancements such as fully digital operations, encryption capability and other features essential to police operations.

Moose Jaw

The Moose Jaw Police Department has within the last two years implemented a fully digital **Motorola** ASTRO® APCO-25 fully compliant trunked 800 MHz radio system that provides the latest in technology advancements such as fully digital operations, encryption capability and

other features essential to police operations. The City also operates a single site VHF system. No further information is available on this system.

City of Regina

Regina is in the process of upgrading their 12-year-old **Motorola** SMARTNET II™ Hybrid City-wide trunked system to a fully digital trunked radio system with analogue capability. Regina was the first city in Canada to have a shared trunked City-wide system, the SMARTNET II™ Hybrid system (11 channels in use including the control channel). It has been operating since 1989. The system was purchased from Motorola by the City (jointly with Regina Police Services) with the intention of first serving Public Safety agencies and gradually bringing on all other City agencies. Within 18 months, all City agencies were on the system, using a total of 1167 radios.

Backhaul was initially microwave (23 GHz) but experienced serious fade problems and lightning strikes. The City is currently leasing T1 lines from SASKTEL, but is investigating the possibility of using, in the future, existing and potentially available city-owned fibre network to provide redundant backhaul facilities.

5.3.3 Public Mobile Communications Networks

SaskTel Mobility operates a **M/A-COM** EDACS 800 MHz province-wide trunking system (FleetNet 800™) used by the RCMP, Public Safety, Public Service and commercial users. Currently, the network consists of 184 tower sites; four switches, one STARgate™ switch; four data gateways and 16 on frequency repeaters. FleetNet 800™ sites and switches are monitored and controlled at the Westwire Switching Centre staffed 7/24 for alarm monitoring and trouble reporting.

The original network was augmented by additional sites in order to satisfy requirements of the RCMP for coverage in less populated areas. The RCMP was considered their anchor tenant. Due to increasing costs to ensure the required coverage and Public Safety grade of service (including priority access for Public Safety agencies on FleetNet 800™) and their need to provide service north of the 54th parallel, the RCMP are now planning to build their own network.

5.3.4 Vulnerability

SaskTel Mobility FleetNet 800™ was built primarily as a commercial network supporting all of SaskTel Mobility Public Services (in many cases existing cellular sites were used) and providing communications for their commercial and a few Public Safety users. As this network carries all of SaskTel's and SaskTel Mobility's services on one infrastructure, this indeed represents a vulnerability. From Lapp-Hancock's work relating to this system carried out in 1999, it has little redundancy, poor reliability, and poor coverage. As such, it can be said to have considerable vulnerability to the natural hazards occurring in Saskatchewan.

In contrast, the cities of Saskatoon and Moose Jaw have recently implemented digital trunked radio systems and are maintaining their analogue systems as back-ups. They can thus be said to have a reasonable level of vulnerability mitigation.

The City of Regina is currently (March 2002) in the purchasing stage of a shared trunked digital system with analogue capability. It is expected to be in service in approximately one year's time. The current analogue system has antenna and control back-ups and again has reasonable resistance to natural hazards. It is important to note that the plans include maintaining the analogue system as a back-up to the new shared digital trunked system. Thus once the new system is in operation, the vulnerability of the Regina system to the potential natural hazards will be very low.

5.4 Manitoba

5.4.1 Natural Hazards

Manitoba is prone to flooding on a regular basis throughout much of the province. This is due to severe weather as well as to the spring thaw. The usual extent of flooding is typically quite small; however, it may occasionally affect several adjoining municipalities or reach disaster proportions as was the case of the Red River Flood in 1997 and on several occasions in the past 50 years.

Manitoba may also experience numerous severe weather incidents including tornadoes, severe thunderstorms, heavy rain, hail, windstorms, blizzards, snowstorms and ice storms. The Eastern and Northern wooded areas of Manitoba are prone to forest fires (an average of 492 fires per year over the last 10 years). As forest fires affect every province in Canada, it was felt appropriate to mention that the prime forest fire-fighting agency in Canada is located in Winnipeg, Manitoba. The Canadian Interagency Forest Fire Centre (CIFFC) – a counterpart of the U.S. National Interagency Fire Center (NIFC) in Boise, Idaho – coordinates the movement of equipment and personnel in all provinces and in support of American fire fighters.

Forest fires are occurring in all provinces on a yearly basis with B.C. and Ontario being typically most affected. To put this natural hazard in the perspective of this study, it is necessary to stress the importance of communications to conduct the operations, to communicate between personnel and Fire Centres, and with the air support. Typically, forest fires do not significantly affect the regular communications network of the various ministries responsible for fire fighting operations in their provinces or territories. A loss of a tower to a fire does not greatly affect the overall operations. The communications towers are far apart and usually forest fires occur or expand into areas not covered by any communications networks. However, communications are essential to prevent loss of life and to minimize significant financial losses in terms of burnt hectares of forest. The telecommunications architecture in general allows the use of repeaters in Fire Camps or even mounted on aircraft to provide communications links where no communications infrastructure exists.

5.4.2 Private Mobile Communications Networks

Provincial Network

MTS Mobility operates a provincial **Motorola** 800 MHz trunking analogue/digital dispatch network (FleetNet 800™) with approximately 100 sites. Among the users are federal/provincial government departments, the RCMP, the City of Winnipeg Police, emergency responders and EMO, mining, and other sectors of private industry. As an analysis of the network and its

performance has not been possible, no valid conclusions or assessments of the network can be made at this time.

5.4.3 Public Mobile Communications Networks

The MTS Mobility infrastructure carries paging, cellular, PCS and other services while Rogers Wireless Inc. (Cantel) has cellular coverage in Manitoba. In addition, Integrated Messaging Inc., with its headquarters in Winnipeg, provides a wide range of advanced messaging services (alphanumeric paging) and has a 24-hour call centre.

5.4.4 Vulnerability

The MTS Mobility infrastructure provides telecommunications services to a variety of government departments, and carries commercial services such as paging, cellular, and PCS. A common infrastructure such as this may increase vulnerability as it can provide a *single point of failure* for all services carried.

From historical accounts of the performance of various networks deployed in Manitoba during the Red River Flood in 1997, the following assumptions can be made. Flooding in Manitoba can restrict access to some MTS Mobility sites and can affect landlines, severely impacting a number of services. Depending on the number of channels available to Public Safety organizations in areas prone to flooding, capacity may also become a problem. The Red River Flood in Manitoba in 1997 was a recent example of a wide-area flood disaster where the performance of telecommunications networks was closely monitored by the Government Emergency Operations Coordination Centre (GEOCC) activated in Ottawa and supported by Industry Canada's Emergency Telecommunications Branch. The following information was extracted from their report:[28]

- During the flooding Stentor had one telephone exchange out of service due to flooding but it only affected 250 lines. Some local lines were not available because of flooding of the Remote Concentrator Units (Pedestals).

- The national optical fibre trunk continued operating under water without difficulty.

- The Province of Manitoba and the RCMP had to relocate some of their radio sites.

- The cellular systems were initially overloaded. To mitigate this situation, the two cellular companies Manitoba Telephone System (MTS) and Cantel relocated some of their cells. In addition, portable cells were installed in remote areas to provide service for emergency personnel.

- MTS Mobility also increased the capability of its public dispatch-based service, FleetNet 800™, to assist in meeting the demands of the emergency agencies.

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[28] See Bibliography, Item 61.

This report on the performance of various networks deployed in Manitoba during the flood demonstrates that flooding can affect land lines (phone lines) and may affect the operation of certain transmit/receive sites (again mainly those connected by land lines) in the immediate impact area. It also supports our statement that public systems, in this case cellular networks, suffered severe overloading and were virtually unusable for emergency operations at the onset of a critical situation until affected cells were moved or portable ones installed to support the increased traffic.

This study showed that from a vulnerability point of view, there were numerous problems with communications systems operating in Manitoba. However, these vulnerabilities may have been mitigated since the Red River Flood of '97.

5.5 Ontario

5.5.1 Natural Hazards

The Province of Ontario experiences a variety of severe winter weather conditions such as snow and ice storms but these are typically limited to certain regions. The most recent major natural disaster was the Ice Storm of 1998, which affected all of Eastern Ontario. In the past, disastrous flooding and tornadoes have also occurred. Southwestern Ontario has approximately 10 tornado events per year per 10 000 sq. km. In addition, there are 1520 forest fires on average per year.

5.5.2 Private Mobile Communications Networks

a) The RCMP

The RCMP is currently using a 15-year-old **M/A–COM** communications network.

b) The Ontario Government

Until recently, the Ontario Government, acting through the then Ministry of the Solicitor General, operated five province-wide, two-way radio networks for the following entities:

- Ontario Provincial Police (OPP)
- Ontario Correctional Services
- Ministry of Health
- Ministry of Transportation
- Ministry of Natural Resources

In June 1998 an agreement was signed between the Ministry of the Solicitor General and Bell Mobility Radio for a fifteen-year partnership, effective 1 July 1998. This partnership would first amalgamate the networks of the five Ontario government entities, and then work toward upgrading them to digital trunk technology based upon the *evergreen philosophy*, whereby the equipment and infrastructure were reviewed periodically in a non-disruptive manner to maintain it as a *state-of-the-art* network. At the same time, the Ontario government formed the Government Mobile Communications Office (GMCO), a team of managers co-located with Bell Mobility Radio and who collectively formed the project management office to ensure that all

Ontario government needs were met and to participate in establishing objectives, schedules, and solutions.

A key and innovative clause of the agreement between the Ontario Ministry of the Solicitor General and Bell Mobility Radio permits the latter to use the network to provide services to Ontario municipal and regional Public Safety and Public Service entities in addition to the GMCO. The priorities of the GMCO must first be met, but Bell Mobility Radio, with support from the GMCO, are free to quote on the provision of mobile communications services to regional and municipal entities that require them.

The Bell Mobility FleetNet 800™ radio communications system is based upon **Motorola's** SmartZone™ trunking system technology, operating in the upper VHF frequency band. The network supports both digital and analogue communications throughout Ontario up to 51° North. It provides a level of service of 99% availability.

The FleetNet 800™ network is divided into five zones as follows:

- NorthWest
- NorthEast
- Central
- SouthWest
- SouthEast

Each site has a number of channels (typically four to six) chosen to meet specific user needs. Each zone has its own network controller to provide management and network and network interfaces. Dispatch consoles in Communication Centres are interfaced directly to the network via wireline connections.

Other features of the design include the following:

- enhanced portable radio coverage provided by vehicular repeaters cross-connected to the trunking mobile radios;
- conventional portable radios operating in the UHF band are proposed to communicate with other portable radios (or dispatch) via the vehicular repeater; and
- specific requirements of individual agencies, such as stand-alone portable coverage or in-building coverage can be accommodated by the addition of layers of infrastructures for example repeaters and receiver sites.

After all zones have been implemented (by 2005), *evergreening* of the network will take place on a routine basis to keep it at the forefront of technology. The current agreement expires in June 2013.

c) Ontario Municipalities

In the last five to ten years, Ontario has been undergoing a number of amalgamations of its cities and surrounding municipalities in order to create more cohesive forms of local government. This

process often required substantial changes to the telecommunications infrastructure to serve the new cities. From the telecommunications perspective, this move was very timely as most of the small municipal radio networks had come to the end of their useful life. In addition, a typical drawback was lack of interoperability that could severely impact the response of local Public Safety organizations to a disaster scenario. With the implementation of new networks covering larger geographical areas, the response to local disasters can be managed in a better way, providing at least some degree of interoperability that did not exist before.

The following information on the Public Safety and Public Service networks of Ontario municipalities is presented in West to East order.

Thunder Bay[29]

The City of Thunder Bay Police currently operates a conventional **Motorola** system in the 136 to 150 MHz band.

Thunder Bay Police have recently commenced the process of replacing this system. It is hypothesized that this is to provide the police with the encryption capability of a digital system.

Sault Ste. Marie

The City of Sault Ste. Marie has a new shared **Motorola** ASTRO® conventional network with three sites. The services using this system are currently unknown.

Sudbury

The City of Sudbury operates a shared five-site, 15-channel EDACS® (**M/A–COM**) system. The services using this system are currently unknown.

Windsor

The City of Windsor has a **Motorola** 800 MHz trunked system (three sites) for Police and Fire.

London

The City of London Fire service is using a two-site **Motorola** network, whereas London Police uses a three-site, 20-channel EDACS® (**M/A–COM**) system, implemented during the 1995-1996 timeframe.

Owen Sound

The City of Owen Sound operates an aging **M/A–COM** network.

Niagara Region

The Niagara Region was contemplating becoming the first regional customer on Bell Mobility's FleetNet 800™ network (see Government of Ontario network above). However, due to difficulties with the design and several operational issues, they are now implementing a

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[29] See Bibliography, Item 57.

conventional VHF ASTRO® 20-site Motorola network serving Police and Fire. The details of the difficulties with the FleetNet 800™ system have not been released.

Kitchener-Waterloo

The City of Kitchener-Waterloo has an EDACS® (**M/A–COM**) network for Police and Fire with 7 to 10 sites and approximately 12 to 15 channels. It was implemented around 1992.

Guelph

On October 14, 1999 the Guelph Police and the Guelph Fire Departments became the first municipality to join Bell Mobility's (**Motorola**) FleetNet 800™ system (See Government of Ontario network above). FleetNet 800™ has replaced the conventional VHF systems operated by the Police and Fire Departments and will accommodate operations of three communications Centres for these Departments. It supports 178 mobile and portable radios and provides state-of-the-art two-way communications to these Public Safety agencies. No additional information is currently available.

Hamilton

The new City of Hamilton has an eight-site, 16-channel 800 MHz **Motorola** SmartZone™ system serving Police and Fire.

Halton Region

The Halton Region has an EDACS® (**M/A–COM**) network serving all agencies (12 sites).

Peel Region

The Peel Region has an eight-site, 17-channel (**Motorola**) SmartZone™ system serving Public Safety and local government agencies.

Toronto

The integrated Police and Fire communications (**Motorola**) system is an 800 MHz trunked system, currently used by the new City of Toronto. It has the capability of further sharing. The integrated system was built on and leverages the pre-existing infrastructure of the six former Metro Toronto Area Fire Departments and the Metro Toronto Police. There are two dispatch centres in the system; one for Fire Services and one for the existing Police Centre. In the final configuration, the main Police Centre will operate as the backup centre for the Fire Service and vice-versa.

This integrated radio system subdivides the new City of Toronto into four SmartZone™ simulcast subsystems. The South (Central) Zone operates a 20-channel 800 MHz trunking system, simulcast from five (5) repeater locations. The remaining three Zones each have an eight-channel system, with the North Zone operating three, and the West and East Zones operating four repeaters each.

Barrie[30]

The City of Barrie has a two-site simulcast **Motorola** ASTRO® conventional network with six channels upgraded in March 2001.

York Region

York Region operates an 800 MHz **Motorola** seven-site, 10-channel simulcast network built for the Police Services, and now shared with the Fire Services.

Durham Region

Durham Regional Police Service operates the iDEN™ **Motorola** Public Safety Solution network built by Clearnet (now Telus) in 1997-98, using 13 existing commercial tower sites and adding 29 sites to cover its entire area of 2600 sq. km. Thus, there are currently 42 tower sites serving the Durham Police voice and data network. A very considerable amount of work by Clearnet went into providing a Public Safety Grade of Service network for the Police.

The Fire Services in the Southern portion of Durham Region (Pickering, Ajax and Oshawa) have chosen to implement their own **Motorola** radio network. The prime reason for this is that the iDEN™ Public Safety Solution does not currently provide a simplex operation essential for Fire Services in their on-scene operations. In addition, the user equipment (portable radios) has small buttons which are difficult to operate when fire fighters' heavy gloves are worn.

Kawartha Lakes

The emergency and city operations that will serve the new City of Kawartha Lakes (previously Victoria County, Ontario with Lindsay as its county town) are currently using a number of separate radio systems. Most of the systems are stand-alone small systems of various ages. A number of agencies contract services from local service providers (T.A.S. Communications, T.A.S. Page and Stellar Communications), located in Peterborough. Interoperability between agencies on different systems is often difficult as they have not been engineered to the same criteria.

The Lindsay Police Service owns and operates their own base/repeater station. The Lindsay Police Service owns nine mobile radios, 17 portable radios and four mobile repeaters. For the last 15 years Lindsay Police Service has also been dispatching the Lindsay/Ops Fire Department.

The individual Fire Departments serving the City of Kawartha Lakes operate a number of small systems typically provided by local service and equipment providers and own in total 79 mobile radios, 150 portable radios and five mobile repeaters using 20+ VHF channels. There are 19 fire stations and 79 pieces of fire apparatus in operation throughout the region. The common Mutual Aid frequency is quite often used for operations and dispatch.

The City's Public Service radio system, again supplied by local equipment providers, operates 156 mobile radios and uses 15 portable radios. The Volunteer Fire Services use 246 voice pagers, and 150 alphanumeric pagers are in use in the Victoria County.

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[30] See Bibliography, Item 58.

Cobourg

The City of Cobourg has a new **Motorola** 800 MHz trunked network shared by the Police and Fire Services. No further information is available.

Belleville

The Belleville Police Service is operating a 15-year-old, two-channel VHF **Motorola** analogue conventional system. An upgraded system is currently being tendered for the new city. No further information is available.

Kingston[31]

The Kingston Police are in the process of replacing their current **Motorola** VHF radio system that was purchased in 1975. This VHF system consisted originally of four sites (two transmit/receive sites and two receive only sites) and repeaters for the two operational channels. Following the creation of the *New* City of Kingston in 1998 and the conclusion of a contract with the Ontario Provincial Police in 1999, the Kingston Police assumed policing responsibility for the entire new city. The Kingston Police now has jurisdiction over an area of 528 sq. km. As a direct result of the amalgamation, the coverage provided by the VHF system was insufficient. One radio tower had to be relocated and an additional *receive only* tower added to provide mobile coverage. Currently Kingston Police carries both VHF and UHF portables, the latter being used in certain areas only.

The City is currently (2002) investigating the implementation of an advanced system, shared by all City Public Safety and Public Service organizations to mitigate the coverage and other problems of the old systems.

Ottawa[32]

The new City of Ottawa owns and operates a three-year-old system, an 800 MHz Ericsson (**M/A–COM**) EDACS® trunked digital system with analogue capability, built for about $20 million, that currently supports approximately 1700 users. The members of the Regional Police are the largest users.

The system is comprised of nine transmit sites, seven of which are Simulcast. There are eight additional receive-only sites to ensure adequate coverage to hip-worn portable units. Coverage target was 95% availability for hip-worn portables. This target is generally exceeded throughout the system for outside coverage, with coverage being 100% for Ottawa and Nepean. Cumberland and West Carleton have a few areas with coverage deficiencies. The Regional system uses an omnidirectional antenna with a large antenna pattern downtilt to provide close-in coverage and to minimize interference with other sites through nulling the signal (-16 dB gain) on-horizon.

The system has been configured for 15 channels and currently operates with 10 channels. The seven simulcast transmit/receive sites each employ three separate identical antennas, with the radio channels divided among them. When fully configured with 15 channels, each antenna

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[31] See Bibliography, Item 44.

[32] See Bibliography, Item 36.

would have five channels. The system was built with data capabilities as part of the system design, although the Regional Police continue to use Cellular Digital Packet Data (CDPD) from Bell Mobility Radio. An EDACS® Data Gateway (EDG) is installed, but is not currently used for operational data transmissions.

The RCMP shares the police section of the regional network; its members represent only a small proportion on the system with some 47 users.

5.5.3 Public Mobile Communications Networks[33]

Ontario is served by the following cellular/PCS networks:

- Bell Mobility
- Microcell
- Rogers AT&T Wireless
- Telus Mobility

All major cities within Ontario, including but not necessarily limited to Ottawa, Toronto, Kitchener, Hamilton, Niagara-on-the-Lake, Niagara Falls, Kitchener-Waterloo, London and Windsor are covered by all four systems. In addition the major highways from the Québec border to Windsor, from Ottawa to Highway 401, and from Hamilton to Niagara Falls are also covered by all four systems. Sudbury has an independent public cellular system.

5.5.4 Vulnerability

There are still many small aging networks used in Ontario. The deployment of the two proprietary networks (Motorola and M/A–COM (formerly Ericsson)), often in a sequential manner, presents interoperability difficulties between neighbouring regions during a widespread natural disaster. The wide range of types, age and size of Ontario's Public Safety and Public Service systems is reflected in their estimated vulnerability. Major redundant systems such as Toronto's Police and Fire system are estimated to have little vulnerability to natural disasters. Many of the medium-sized cities and regions have also upgraded their systems comparatively recently, and operate shared trunked systems that provide considerable mitigation against the natural disasters likely to occur in Ontario.

However, many of the medium-sized and smaller cities and regions operate unshared or shared systems that are at or beyond their expected lifetime. These systems have none of the modern features that provide natural disaster mitigation and can thus be said to have a high level of vulnerability. In summary, it can be said that the vulnerability of the systems in Ontario requires case-by-case analysis.

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[33] See Bibliography, Item 59.

5.6 Québec

5.6.1 Natural Hazards

The Province of Québec experiences frequent floods, landslides (many triggered by heavy rains) and severe weather such as ice storms and snowstorms. These natural hazards are typically limited to certain regions, with the exception of the Ice Storm of 1998 that impacted a large portion of Southern Québec.

5.6.2 Private Mobile Communications Networks

The Direction générale des télécommunications (DGT), under the Québec Treasury Board Secretariat, manages five governmental wireless networks that are now about 30 years old. Plans are under way to build a new province-wide unified network to replace these obsolete systems in the 2002-2004 timeframe. The new province-wide network will not only modernize the telecommunications infrastructure, it will also ensure the interoperability between all government departments and will be built to the recognized Public Safety standards. It is expected that in 2004 the Sûreté du Québec, which is currently leasing a VHF province-wide radio network in the 480 MHz band, would also share the network when the lease of their current network expires that year.

On the municipal side, there are currently 124 municipal police forces in Québec, (as compared to 69 in Ontario), each operating their own radio network. The Québec government has initiated the process of reorganizing its police forces (a new law on policing was passed in June 2000) and is proceeding with a reform that will see all municipalities under 50 000 inhabitants policed by the Sûreté du Québec if they so wish. The Montréal Urban Community Police Department (Service de police de la Communauté urbaine de Montréal - SPCUM) is currently using its own 12-year-old Ericsson UHF network operating in the 410-420 MHz band. However, following the amalgamation of communities surrounding Montréal, the SPCUM will be considering the implementation of a new radio network to serve the new City of Montréal.

The Québec Fire Services are even more numerous than the Police Services and are also currently undergoing a major reorganization.

5.6.3 Public Mobile Communications Networks

Québec is served by the following cellular and PCS providers under the oversight of the DGT:

- Bell Mobility
- Microcell
- Rogers AT&T Wireless
- Telus Mobility

Microcell, Bell Mobility and Rogers AT&T have extensive wireless networks throughout the province; Telus Mobility has reselling agreements for their services and Telus/Clearnet also have some coverage in Québec. Communications Métro Montréal Inc./Télé-Page offers provincial, inter-provincial and national paging services on VHF and 900 MHz FLEX (satellite) and alphanumeric and live dispatch services.

5.6.4 Vulnerability

Most municipalities currently have their own telecommunications networks and, in many cases, each Public Safety service operates a different network. The majority of these networks are old and there is no interoperability between them. As mentioned above, the Québec government operates five 30-year-old networks. The normal average life span of any network is typically around 15 years. After that time parts become hard to obtain and reliability becomes questionable.

Based on the above findings the vulnerability of telecommunications networks currently in use should be a major concern not only regarding natural hazards, but also regarding day-to-day operations of Public Safety agencies in Québec. Most of the existing municipal and governmental networks are at the end of their useful lifetime. Due to the extremely large number of existing small networks used by Public Safety agencies, a detailed analysis is not impossible. A major funding effort will be required to upgrade or replace the Québec Public Safety and Public Service infrastructure.

5.7 New Brunswick

5.7.1 Natural Hazards

New Brunswick is prone to floods, snow, and ice storms as well as forest fires (on average about 473 a year).

5.7.2 Private Mobile Communications Networks

The New Brunswick government owns and operates a province-wide private radio network known as the Integrated Radio Communications System (IRCS). The system is used for routine departmental operations and as the provincial emergency radio network. The system includes some 25 EMO repeaters linked through a microwave backbone system to a central electronic switch at the Provincial Mobile Communications Centre (PMCC), in Fredericton. The users on the IRCS are the provincial EMO, police, fire and ambulance agencies, federal/provincial government, GSARs, and the RCMP.

5.7.3 Public Mobile Communications Networks

This data is not currently available.

5.7.4 Vulnerability

At this time we lack sufficient in-depth knowledge of existing telecommunications networks to provide a useful assessment.

5.8 Nova Scotia[34]

5.8.1 Natural Hazards

Due to its geography, Nova Scotia is susceptible to the following natural hazards:

- Hurricanes (According to Environment Canada, Nova Scotia is statistically way past due for a very severe hurricane – it has been more than 30 years since the last one.)
- Severe winter storms (Nova Scotia lies on the Eastern North America winter storm track.)
- Ice storms (Nova Scotia averages several wide-area, but not province-wide, ice storms a year.)
- Electrical storms (Nova Scotia has seen an increase in severe electrical storm activity in a number of areas of the province with increased property loss and power and telephone outages.)
- Forest fires (Nova Scotia experiences several hundred forest fires a year, and while losses are being reduced, many of these fires occur in urban interfaces.)

5.8.2 Private Mobile Communications Networks

The Province of Nova Scotia

In 1999 the Province of Nova Scotia (PNS) entered into a ten-year agreement[35] with Maritime Telephone and Telecommunications Mobility (MTTM) for the provision of a new province-wide shared Trunked Mobile Radio System (TMRS) with an option to extend until 2015. The PNS is considered the *anchor tenant* with over 4,000 users.

The user groups of TMRS include the Royal Canadian Mounted Police (RCMP), N.S. Emergency Health Services (EHS), Department of Natural Resources, Department of Transportation and Public Works, EMO and Volunteer Public Safety Organizations. The volunteer users include Volunteer Fire departments (314), Ground Search and Rescue Teams (26), Municipal Emergency Measures Coordinators (55) and others. At the present time (2002), the TMRS as a whole serves close to 5000 users.

The TMRS utilizes the **Motorola** SmartZone™ system with 68 tower sites operating in the 850 MHz frequency band, and provides over 90% land coverage within Nova Scotia.

The main Halifax site is a 14-channel site. While the majority of the remote sites have two channels (plus a control channel), there are several with up to ten channels. In total, there are 250 repeaters including ten for the Halifax Police, which has a three-site trunked system, but the Police have recently migrated onto the TMRS network. The Halifax Fire Department is also migrating to the TMRS.

The two zones of the TMRS are the Western/Southwestern Nova Scotia Zone and the Northern Nova Scotia/Cape Breton Island Zone. MTTM is responsible for the transport of all traffic associated with the TMRS, including the provisioning of zone controllers and their associated audio switches together with any interconnections required.

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[34] See Bibliography, Item 39.

[35] See Bibliography, Item 39.

The TMRS backhaul uses fibre optic trunking, with the exception of four copper links. In general, the fibre links are redundant, using in most areas SONET fibre ring networks. The main SONET fibre ring (which carries other MTTM services as well as the TMRS) is configured for a 192 DS-3 (one DS-3 has a capacity of 45 Mbps). The ring includes Nova Scotia, P.E.I. and New Brunswick. This ring has a total distance of some 600 km and a split is planned in the short term. In addition, there are two linear fibre optic links between Halifax and Saint John that back each other up. The system architecture has been designed with *gentle degradation* or *fail soft* features such as *site trunking* and the ability of sites adjacent to a failed site to pick up all of its traffic which is in range.

For 16 years prior to implementing the TMRS, the Province of Nova Scotia operated a stand-alone VHF radio system called the Nova Scotia Integrated Mobile Radio system. It has 24 sites and a microwave backbone. This VHF network is still operational and will be maintained by the Province of Nova Scotia as a back-up system. It should be noted that the maintenance and use of such a back-up system is comparatively unusual and significantly reduces vulnerability to natural hazards.

5.8.3 Public Mobile Communications Networks

Two other communications companies operate in Nova Scotia.

Digipage Communications provides voice, alpha, numeric and tone radio paging in the greater Metropolitan Halifax, Truro, Kentville and Wolfville areas. In addition, DownEast Communications provides paging and other communications services in 36 locations throughout Atlantic Canada. Two national cellular/PCS carriers also provide their services in Nova Scotia – Cantel and Telus. (Cantel provided invaluable services during the Swissair Flight 111 crash off Peggy's Cove by allowing the use of their sites when the existing telephone lines were severely overloaded.)

5.8.4 Vulnerability

The Province of Nova Scotia has recently completed a Threat/Risk Assessment of its TMRS network, and a number of mitigation measures are currently being implemented. This Threat/Risk Assessment, carried out by Lapp-Hancock, was very comprehensive and addressed, to a large extent, man-made risks and security weaknesses and thus does not form part of this work. In addition, it is not in the public domain. However, a vulnerability mitigation methodology was conceived during that work, and used for this work, and is detailed in Section 6.2. This methodology was used to assess the vulnerability of the system to natural hazards, to identify the probability of occurrence, to identify the vulnerability of the community to these hazards, to identify mitigation options, and to assess the cost of implementation together with the potential benefits. All of this information is provided in Section 6.4.5.

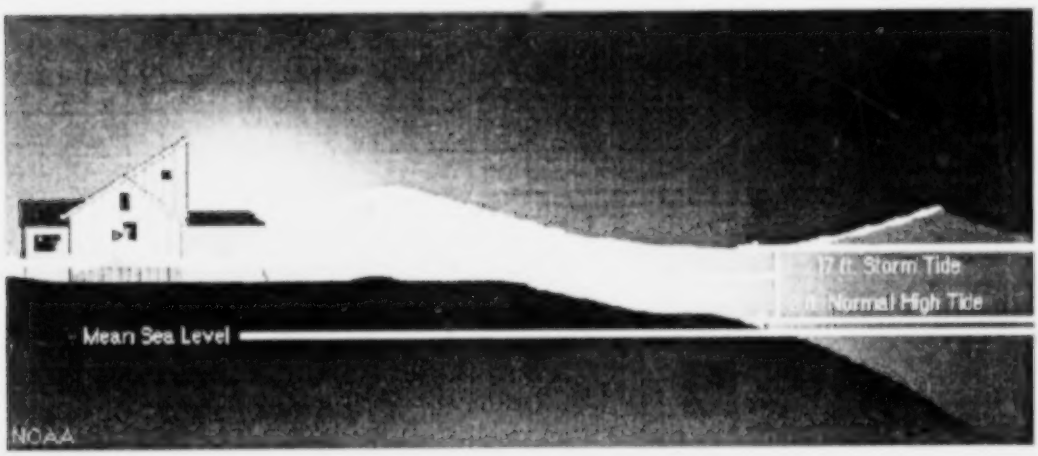
5.9 Prince Edward Island

5.9.1 Natural Hazards

Prince Edward Island faces, on a regular basis, various threats of severe weather. Wind and ice storms occur annually. P.E.I. lies directly on the Eastern North America winter storm track. Hurricanes impacting the Eastern shore are considered a major threat. The threat of dangerously high storm tides has also become very real and, probably due to global climate changes, their occurrence is increasing. The greatest potential for loss of life related to a hurricane is from storm tides. Storm surge (water that is pushed toward the shore by the force of the winds) combines with the normal tides to create the storm tide. This can increase the water level 4.6 m (15 ft.) or more above a normal high tide. This can cause severe flooding in coastal areas, particularly when the storm surge coincides with the normal high tides. The storm tide threat is a major concern of emergency managers in P.E.I.

As this is a comparatively unusual natural hazard it is shown in diagrammatic form in Figure 7.

Figure 7 Storm Tide Diagram
(Source: National Oceanic and Atmospheric Administration [NOAA])



5.9.2 Private Mobile Communications Networks

The Provincial Mobile Radio Network

The province's Public Safety and government infrastructure is served by a **Motorola** trunked six-site provincial network built and serviced by Island Tel. Before the implementation of this radio network in 1988, the main concern of emergency planners was the survivability of antennas in high winds and other severe weather conditions (i.e. ice storms). Therefore, one of the main thrusts behind this network was the mitigation of this vulnerability.

The network has a microwave backbone at this time which, subject to the availability of capital in the future, will be replaced by fibre backbone. Listed below are the current users of the network:

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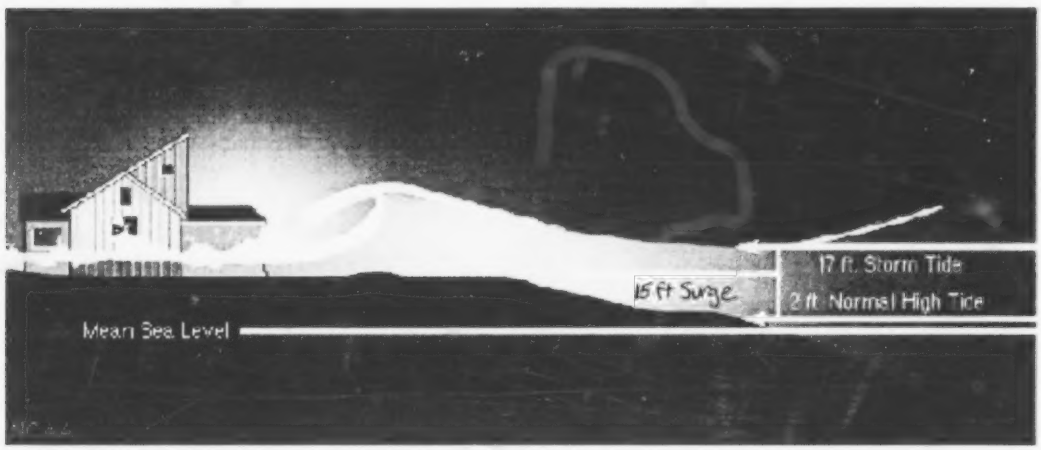

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The network has a microwave backbone at this time which, subject to the availability of capital in the future, will be replaced by fibre backbone. Listed below are the current users of the network:

- Fire Departments
- Fire Marshall's office
- Police
- Ambulance (four private ambulance companies)
- Emergency radio in hospitals
- GSAR and CASARA (both search and rescue organizations)
- Provincial Environment including Spill Units
- Parks
- Charlottetown Airport

The RCMP and the Coast Guard also have access to the network, while maintaining their own communications networks. Also connected to the provincial network are four emergency centres and three PSAPs. The large number of users on this trunked system ensures a high level of interoperability.

RCMP

The RCMP uses a **Kenwood** UHF radio network servicing five RCMP detachments in the province – Bordeaux Carleton, Bridge, Summerside, Kensington and Charlottetown. Redundancy measures include generators and access to HF, UHF and satellite communications.

5.9.3 Vulnerability

While no direct information on vulnerability could be obtained from Lapp-Hancock's contacts on Prince Edward Island, the following estimates of vulnerability can be provided based upon the information that is known. The current provincial mobile radio network is 14 years old; it is shared and had been designed to accommodate the high winds and other severe natural hazards occurring in Prince Edward Island. However, it is unknown whether the current microwave backhaul (or the fibre optic backbone that is hoped will replace it) have redundancy in the form of a ring architecture or redundant linear distribution mechanisms. If it is not so, and it appears unlikely, the fact that all Public Safety and many Public Service systems share the network and its backhaul system would represent a high level of vulnerability, particularly in low lying areas.

5.10 Newfoundland and Labrador

5.10.1 Natural Hazards

Natural hazards include severe winter storms or possibly hurricanes coming up the Eastern coast and making a landfall on the Newfoundland coast. Storm surge could also pose a hazard as well as other localized flooding. The year 2001 will be remembered for a record high snowfall.

Forest fires are a yearly occurrence. Based on a ten-year average, the 2000 fire season in Newfoundland and Labrador was above average in terms of the number of fire starts but below average in terms of the number of productive hectares burned. The Province recorded 219 forest fires, which burned a total of 148 820 hectares. The majority of this area was in Labrador and was non-productive forest.

5.10.2 Private Mobile Communications Networks

RCMP

The RCMP provides policing services in Newfoundland. Their new voice and data telecommunications infrastructure and equipment were supplied by **MA/COM** between 1999 and 2000. At this time (February 2002), the RCMP are looking into the reconfiguration of the existing radio system and an extension of this system within Newfoundland to meet the current and future needs of the RCMP within the province. It is likely that this modern network will meet the latest Public Safety standards and thus mitigate the current mobile communications vulnerabilities.

5.10.3 Public Mobile Communications Networks

Now essentially unique in Canada, the provincial telephone company, Newtel, has no competition. This has inhibited the development of both private and public networks. Newtel has a major system of repeaters and towers that provides island-wide coverage from East-to-West and North-to-South. Newtel Mobility provides cellular service in the St. John's area and, to a large extent, along the Trans-Canada Highway.

Hitech Communications Ltd., located in the town of Corner Brook near the island's West coast, serves many communities with populations of between 10,000 and 20,000. They operate within a 400 km radius of Corner Brook and also provide paging services for small hospitals and volunteer fire departments. Hitech Communications uses Zetron products to extend radio coverage to remote logging camps using mountain top repeaters.

5.10.4 Vulnerability

As mentioned above, there is little definitive information available on either the RCMP network or the public networks on which to give a vulnerability analysis. According to Lapp-Hancock's hypothesis of vulnerability based upon this limited information, the main vulnerability that can be expected in Newfoundland and Labrador is the lack of coverage in remote areas. The systems that do exist appear to be modern. One could validly expect the RCMP system to be digital but not shared. Similarly, the public network has limited coverage, mainly of large communities and the Trans-Canada Highway. From the limited information available on the performance of mobile networks in recent heavy storms, it appears that, in their primary coverage areas, considerable mitigation of this type of natural hazard has been achieved.

5.11 The Three Territories

With a total population for the three northern territories of less than 100 000, the main problem is one of coverage over these vast areas. It should be noted that much of the North is at or beyond the coverage limits of Telesat Mobile Inc.'s mobile satellite communication system. Globalstar, a commercial mobile communications system with polar coverage, has recently gone into receivership, following other commercial low earth orbit mobile communications satellite constellations.

5.11.1 Natural Hazards

Forest fires, earthquake hazards and limited spring flooding represent the major natural hazards for the North.

5.11.2 Private Mobile Communications Networks

Mobile communications are considered an essential service in these remote areas. The Government of Yukon owns and operates the Multi-Departmental Mobile Radio System (MDMRS), the VHF system built by Northwest Tel in 1991 consisting of 46 repeaters. There are currently 18 user groups (approximately 1100 users) on this network.

In 2001, the Government of Yukon commenced a six-year project to replace MDMRS with next generation technology. The project calls for an integrated, three-prong solution which will incorporate a conventional VHF P25 public safety radio system with existing cellular networks and MSAT coverage for outlying rural areas. This system will provide safety and protection by assuring stable communications to 22 northern communities and 3500 km of Yukon highway. A technical working group and a projects steering committee headed by the territory's Department of Highways and Public Works includes representation from Industry Canada, the Royal Canadian Mounted Police (RCMP), First Nations, municipal governments, utilities and user groups.

Policing is provided entirely by the RCMP, while Forestry has its own communications network with 10 mountaintop repeaters for fire suppression.

5.11.3 Public Mobile Communications Networks

Northwest Tel has its own public telecommunications network serving commercial customers and the general public.

5.11.4 Vulnerability

The Yukon, Northwest Territories, and Nunavet have a combined population of about 93 000, much of this concentrated in the three cities of Whitehorse, Yellowknife, and Iqaluit. Given the criticality of mobile communications within the territories and the harsh environmental conditions (as distinct from natural hazards), it is considered likely that mobile communications users had adapted to the normal harsh conditions, thus the natural hazards that can be foreseen are likely to present only a comparatively small incremental vulnerability. When this is considered with the vast area and small population, a working hypothesis is that the North as a whole could be classified as a low risk area with regard to Public Service and Public Safety mobile communications.

6.0 Case Studies

6.1 Selection Criteria

To further expand upon the network specific information provided in Section 3.0, two case studies are provided. The following selection criteria were used:

- Should be modern systems demonstrating as many of the new Public Safety technologies as possible
- Should be in significantly different natural hazard high-risk zones
- Should be of significant size and importance to Canada
- Should, if possible, be in widely separated geographic zones
- Should demonstrate mitigation approaches and methodology
- If at all possible, should demonstrate the differences between old thinking and new in relation to Public Safety mobile communications and approaches to natural hazards

Using these criteria as guidelines, the following examples were selected for these case studies:

- The Capital Regional District of B.C.
- The Province of Nova Scotia's Trunked Mobile Radio System (TMRS)

These are provided in Sections 6.3 and 6.4.

6.2 Vulnerability Mitigation Methodology

It is perhaps self-evident that the mitigation of all vulnerabilities, regardless of impact, would be a major task, would incur significant financial cost, and would be logically dealt with on an incremental basis. The following mitigation prioritization methodology was therefore developed by Lapp-Hancock, under work carried out for the Province of Nova Scotia,[36] and is used in both of these case studies to classify and prioritize natural hazards vulnerabilities. Each vulnerability is addressed in terms of:

- cause
- probability of occurrence
- vulnerability of the community (impact)
- mitigation option(s)
- cost to implement mitigation option(s)
- estimated benefit

Probability is defined as the likelihood of the hazard occurring in any given 12-month period. It is primarily an estimate based on future probabilities identified through third party research. These rating values are weighted equally and are individually defined, to the extent possible, as follows:

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[36] See Bibliography, Item 39.

Natural Hazard Parameters	Rating	Description
Cause	N.A.	• Identified on a case-by-case basis
Probability of occurrence	High	• 75% or greater probability of occurrence
	Medium	• 25% or greater probability of occurrence
	Low	• Less than 25% probability of occurrence
Vulnerability of the community (impact)	Very High	• Major loss of life and property damage • Major impact on essential services
	High	• Risk of serious injuries and loss of life; property damage • Significant disruption of delivery capability for essential services
	Medium	• No significant safety risk • Limited disruption of delivery capability for essential services
Mitigation option(s)	N.A.	• Identified on a case-by-case basis
	Low	• No safety risk • Disruption of delivery capability within normal operational tolerance
Cost of implementation	Very High	• Costs to implement mitigation measures reach tens of millions of dollars
	High	• Costs to implement mitigation measures reach millions of dollars
	Medium	• Costs to implement mitigation measures reach hundreds of thousands of dollars
	Low	• Costs to implement mitigation measures reach thousands of dollars
Benefit	Very High	• Over 90% of this vulnerability is mitigated
	High	• 75-90% of this vulnerability is mitigated
	Medium	• Over 50-75% of this vulnerability is mitigated
	Low	• Up to 50% of this vulnerability is mitigated

6.3 The Capital Regional District of B.C.

6.3.1 Background

It was decided to use the existing Public Safety networks of the large number of small municipal systems in Victoria and surrounding municipalities and, to the extent possible, compare them with the transition from the current system to the implementation of a new Capital Regional Emergency Services Telecommunications (CREST) network for the Capital Regional District of B.C. as the first case study.

Apart from meeting the selection criteria, the risk of earthquakes is particularly high in the southwestern region of British Columbia. The state of emergency preparedness in this region was tested during the winter of 1996/97 by the exceptionally heavy snowfalls that occurred on the Lower Mainland and Vancouver Island. While not being a major disaster, the snowfails and their consequences did raise questions about the capability of the municipalities to deal with an emergency situation. In many communities, transportation routes remained impassable for several days due to the lack of municipal coordination or the lack of activation of mutual agreements, the public was not kept informed on any ongoing efforts to minimize the impact of the snow storm, and the overall emergency management process was hampered by the lack of coordination and direction.

The B.C. Capital Regional District as a whole has gone through the process of reassessing its communications networks and is currently (February 2002) in final negotiations with Motorola for the supply of CREST. The new network will serve 47 stakeholders (including small volunteer fire departments) who are currently operating a number of radio networks that typically do not communicate with each other. CREST has been designed with earthquake survivability in mind.

6.3.2 Current Systems

Details of the current systems serving the RCMP, Victoria, Saanich and a number of smaller Police Departments are given in Section 5.1.2 and for succinctness will not be repeated here.

6.3.3 Vulnerability Assessment and Mitigation of Natural Hazards Potentially Affecting CREST

Cause

Earthquakes: British Columbia is relatively new to the field of earthquake preparedness. Although it has had various forms of civil defence planning over the last 40 years, it is really only since the 1980s, with the growing understanding of the risk, that serious consideration has been given to preparing for a major earthquake. Most of the effort to date has gone into planning for response. The planning for mitigation and recovery programs have been slow to develop.

Another important point is that the seismic safety component contained in Part 4 of the B.C. provincial code does not apply to all structures. Transmission towers are not within the scope of the code and the construction of buildings of fewer than three storeys

	and of an area less than 600 sq. m (which includes many fire halls, ambulance and police stations) are governed by Part 9 of the provincial code which does not contain a seismic safety component.
Probability of Occurrence	High
Vulnerability of the Community (Impact)	High
Mitigation Option(s)	The mitigation of most of the issues currently affecting the various small systems in the CRD (age, coverage, links and redundancy) and their overall lack of interoperability will be addressed by the new CREST system currently being implemented. A remaining vulnerability may be the buildings housing some of the infrastructure (such as dispatch centres and, in some cases, buildings housing radio equipment on top of mountains in the region). The local Geological Survey office (Sydney, B.C.) has expressed some concerns as virtually all systems in the region use Mt. Douglas as a tower site. However, the proposed CREST microwave ring system will mitigate this possible vulnerability to a large extent. Earthquake proofing or any retrofitting of communications building may be an additional mitigation effort required by all users.
Cost of Implementation	Considerable
Benefit	High

6.3.4 The CREST System Currently Being Implemented

The proposed CREST system will be a Motorola SmartZone™ wide-area mobile voice radio system, capable of integrating VHF multicast and 800 MHz simulcast radio frequency sub-systems. SmartZone™ Master Site equipment will be installed at Victoria Police Department Headquarters and supported by a three-site, nine-channel trunked simulcast sub-system, linked by a microwave loop. Five VHF trunked multicast repeater sites will complete the installation. Existing dispatch locations will be maintained and equipment upgraded to CENTRACOM Elite™ dispatch consoles. Most of the locations already have back-up power in the way of UPS and generators. The system will support approximately 1400 mobile and 1250 portable radios. A microwave ring backhaul system will be installed between sites, in addition to RF links to provide back-up to the leased lines currently used to the dispatch points, which will ensure earthquake survivability of the new system.

Vulnerability Assessment

Based upon Lapp-Hancock's knowledge of the CREST system obtained through its work on the development of CREST, a vulnerability estimate of this network, currently being implemented, can be provided. Despite the fact that the network will serve areas that are vulnerable to both tsunamis and earthquakes, a high level of vulnerability mitigation will be achieved. The prime approach has been to link the various sites by a microwave ring system such that if one tower is affected, the signal can be reversed, minimizing the impact of an earthquake. All sites are planned to be located on a mountain top or on a high earthquake resistant building. Thus, the level of tsunami mitigation is also high. Microwave or optical fibre redundant links are proposed between the control centres and the main switch location. This is expected to provide considerable vulnerability mitigation in the case of both major hazards.

6.4 The Province of Nova Scotia's (PNS) Trunked Mobile Radio System (TMRS)

6.4.1 Why This Case Study Was Selected

The PNS's TMRS met the defined criteria, and a detailed Threat Risk Analysis of both natural hazards and man-made threats and risks had been recently carried out on the system. Subsequent to this, mechanisms for the mitigation of the most critical threats and risks had been implemented. Given the fact that the system serves the RCMP and the Halifax Police and has considerable commercial confidentiality, public domain data was used to provide the geo-spatial locations of the system towers. Estimated individual transmitter site ranges were then inserted. This gave a total TMRS coverage estimate. This was in good correlation with actual coverage achieved by the operational system.

An analysis was performed to ascertain the percentage of the areas with duplicate coverage. This helped to confirm that practically all populated areas had significant duplicate coverage, and therefore the disruption of a single site would go essentially unnoticed.

6.4.2 Technical Description of the TMRS[37]

In the interests of succinctness, refer to Section 5.8.2 for a technical description of this system.

6.4.3 The Back-Up System[38]

Prior to implementing the TMRS, the Province of Nova Scotia operated a totally stand-alone VHF radio system for 16 years called the Nova Scotia Integrated Mobile Radio system. It has 24 sites and a microwave backbone. This VHF network is still operational and will be maintained by the Province of Nova Scotia as a back-up system. It should be noted that the maintenance and use of such a back-up system is comparatively unusual and significantly reduces vulnerability to natural hazards.

6.4.4 Natural Hazards Potentially Affecting the TMRS

In the interests of succinctness, refer to Section 5.8.1 for this information.

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[37] See Bibliography, Item 39.

[38] See Bibliography, Item 51.

6.4.5 Vulnerability Assessment and Mitigation of Natural Hazards Potentially Affecting the TMRS[39]

Using the methodology given in Section 6.2, the following vulnerability assessment to natural hazards was carried out.

Cause	With its Northern Maritime climate, Nova Scotia is subject to a wide range of severe weather conditions and other natural phenomena, which can place significant stresses on the emergency services of the Province. While in many ways the four Public Safety services (police, fire, ambulance and emergency measures) are comparatively familiar with extreme weather hazards, the Meteorological Service of Canada states that there is a trend toward these hazardous events becoming more extreme. Statistically, a severe hurricane can be expected at any time, and there is a strong body of expert opinion that predicts that global warming will increase the number and severity of ice storms and electrical storms. The latter can validly be expected to increase the number of forest fires.
Probability of Occurrence	Medium
Vulnerability of the Community	High (all three risk elements given in Section 6.2)
Mitigation Option(s)	The main mitigation options for natural hazards are awareness, planning, practicing emergency preparedness and extended interoperability capability. By their very nature, natural disasters are rare and emergency measures organizations tend therefore to give them lower priority than the more frequent, higher profile police, fire and ambulance emergencies. Thus, the prime mitigation option is to be aware of the potential major impact of natural hazards and to ensure that emergency measures and emergency preparedness organizations are properly equipped and trained. The extended interoperability requirement relates to organizations such as the utilities (hydro, gas, water and sewage) and to Public Works. Other jurisdictions have found that radio communications with these organizations is often a weak point during a natural disaster. It is therefore necessary to ensure that these organizations are included in all planning and operational changes required.
Cost of Implementation	Low
Benefit	High

[39] See Bibliography, Item 39.

7.0 Findings

This research led to a number of findings with regard to the vulnerability of mobile telecommunications to natural hazards. Some of these findings were to be expected, however many others were unexpected and could validly lead to new perceptions of the vulnerabilities of Canada's mobile radio systems. These new perceptions could relate not only to the vulnerability to natural hazards but also to the impact of the variability of standards to which the systems are built, to funding levels, and to the technical sophistication of public and private mobile radio systems throughout the country.

This work has achieved the following results:

- A pool of knowledge on Public Safety and Public Service and cellular/PCS mobile radio networks.
- The recognition of the implications of this knowledge on critical infrastructures.
- The development of databases to organize network information, and to quantify future progress in overcoming system limitations and vulnerabilities.
- The opportunity to make available for discussion and potential use a vulnerability mitigation methodology developed by the authors.
- This work has been able to identify in a generic, but not network-by-network basis, both the potential vulnerabilities of mobile telecommunications to natural hazards and the vulnerability of disaster zones to such mobile telecommunications disruption.

The findings are given below in what is considered to be the approximate order of the impact on the vulnerability of Public Safety and Public Service systems from emergency management and emergency planning viewpoints. In order to facilitate their review, they are broken down into those common to most systems and those that relate primarily to municipal systems.

Findings common to most Public Safety and Public Service systems:

a) Mobile wireless communications are essential to any coordinated effort on the part of the Public Safety and other essential agencies to minimize loss of life in emergencies and for general natural hazard management.

b) The very large number of Public Safety and Public Service mobile communications networks vary widely, particularly at the municipal level, in size, funding, age, technical standards, management styles and competence.

c) There are many technical incompatibilities between Public Safety and Public Service networks, even in adjacent jurisdictions, including at least the following:

- frequency band used (some have VHF, some have lower UHF and some 800 MHz UHF);
- design approach used by the two main suppliers (Motorola and M/A–COM) ensuring that they cannot intercommunicate; and
- lack of interoperability between Public Safety organizations in the same municipality, with those in adjacent municipalities, and with Public Services, even when using the same frequency band and user equipment.

Findings that relate primarily to municipal Public Safety and Public Service systems:

a) In virtually all cases, Public Safety and Public Service mobile communications are considered a tool and a service to assist in meeting the organization's objectives. When it performs this service, it tends to be forgotten. A reasonable, but not necessarily definitive, assessment of interoperability can be obtained by assessing whether a network is trunked and shared between other agencies and emergency service organizations. There are seldom procedures in place for:

- upgrading the system;
- general management administrative guidelines related to the networks;
- the provision of sufficient spare radios and spare parts; or
- training on the user radios (even though there are usually a range of important functions, some of which are only used infrequently).

b) A significant finding is that the vulnerability of Public Safety and Public Service systems to natural hazards has a low priority with virtually all municipal systems. There is some evidence of greater consideration of natural and other hazards by provincial and regional networks that have access to greater funds and have a broader mandate.

c) An important finding of this work is that most of the vulnerabilities of Canada's mobile radio systems, particularly those of the Public Safety and Public Service networks, are common to both natural hazards and other major emergencies. The fact that many of these are not driven by natural or man-made hazards, but are intrinsic in the organization and implementation of the networks, does not lessen the vulnerability of the networks to the impact of natural hazards.

d) With regard to the telecommunications networks survivability, the loss of power typically has a significant impact. Thus, power redundancy measures are important for all essential infrastructures and essential buildings.

e) After a natural hazard occurs, the availability of traffic capacity to deal with the increased volume of use at sites where normally there is very little radio traffic may become an issue. In urban centres, newly-built private networks are generally designed to be able to handle all essential traffic in this situation.

f) Loss of wireline communications mainly impacts the general public and, in some cases, its capability to communicate with Public Safety. Loss of wireline or other type of backhaul facilities in a network would not typically take down an entire private

telecommunications network. Redundant measures are usually built into these networks, and the availability of back-up radio facilities at the dispatch locations will maintain communications between Public Safety and Public Service organizations.

g) Communications towers are not very vulnerable to collapse, even under service stress.

h) During past natural disasters, the public telecommunications networks (cellular, PCS) have experienced overloading in heavily-populated areas immediately in the aftermath of a disaster. However, their availability to first responders in emergencies lasting for an extended period of time has been found to be useful as the public cellular and PCS mobile networks have widespread coverage and are efficient in normal times. Nonetheless, being designed to commercial standards and *normal* traffic loading, they are vulnerable to uncontrollable overloading in emergency and disaster situations. Thus, while they are valuable to Public Safety and Public Service organizations for administrative and non-critical needs, we have found no evidence of them being relied upon in the early stages of emergency or disaster situations.

i) The mobile communications sector is constantly evolving. At the time this report was drafted (February 2002), significant work was being done by local and provincial governments and Public Safety agencies to improve their capabilities to respond to major emergencies.

j) There are some initial indicators (Regina, Saskatchewan, Moose Jaw, and Nova Scotia) of a trend when upgrading to retain the original system as a back-up. This can only be done when the original system is in good condition and is generally limited to when the upgrade is from an analogue system to a digital system.

8.0 Conclusions

It is concluded that the main vulnerabilities of both mobile Public Safety and Public Service networks are common to both natural hazards and to man-made risks and threats. Some of the key vulnerabilities identified are as follows:

a) While the comparatively few provincial wide-area Public Safety and Public Service networks are perhaps the most advanced with some standardization and consideration of vulnerability, the large number of municipal networks have essentially no common standards with respect to operational, technical, organizational or funding matters.

b) A major output of this work is the recognition of the low level of priority given in most municipal and in some regional and provincial networks to natural hazards. While this is less true on a local basis of specific man-made hazards (e.g. chemical spills, derailments, major accidents and fibre optic disruption), day-to-day operational matters tend to edge out the mobile communications management of the more infrequent natural disasters.

c) The fact that we have obtained no evidence that municipal systems give any priority to their vulnerability to natural hazards is a vulnerability in itself. Paradoxically, it is likely that this can be overcome comparatively inexpensively through training and simulations of natural hazard events, particularly for shared systems with trunked capability. This doesn't mean to say that training and simulation should not be carried out with respect to the older, conventional and unshared systems, only that such training is likely to be more effective if the appropriate networks are in place.

d) In most municipalities, the management of the mobile radio network is an *add on* to a range of other responsibilities for either a given officer or whoever happens to be available when things go wrong. Maintenance is frequently sub-contracted out to the local radio shop. There is frequently a lack of interest in mobile communications unless the network fails.

e) There is a lack of long-term municipal planning at the municipal council level regarding Public Safety and Public Service mobile communications. This usually translates into restricted budgets and, when replacement or upgrade becomes imperative, the elevation of this matter into a major and often controversial budget item.

f) The trend toward retaining operating legacy systems as a back-up greatly adds to redundancy and the mitigation of vulnerability.

g) Although prioritization of public network use is possible from a technical viewpoint, thereby potentially overcoming the overload factor for Public Safety services, little work has been done to implement such an approach. From anecdotal evidence it appears that this is due in part to administrative, operational, and financial complexities requiring significant negotiations between the Public Safety and commercial entities. The Telus operations are an exception to this. It is further concluded that such prioritization could be a major benefit but that a coordinated and planned government policy and approach is likely to be required.

h) To permit improvement, there is a need for a change in the thinking and culture of Public Safety and Public Service mobile communications managers (where indeed these exist). Given the rare occurrence of natural hazards in most municipalities, the *responsibility horizon* does not give them a high priority. Given that many of the vulnerabilities of a mobile communications network are common to both natural and man-made disasters, recent occurrences (i.e. September 11th) may precipitate changes in both systems.

i) The problems affecting vulnerability of the majority of municipal Public Safety and Public Service networks to natural hazards are generally intractable and require:

- recognition of the problem;
- agreed-upon aims and targets;
- greater implementation of standards; and
- funding and other incentives.

j) A key vulnerability of many systems is the lack of interoperability between various types of Public Safety and Public Service organizations. Lack of interoperability in the day-to-day operations of these organizations is typically *worked around* through the use of the individual dispatch centres in order to link up, often by telephone, with the dispatch centres of other local Public Safety and Public Service organizations.

This work-around functions reasonably well for individual emergencies such as accidents and fires that are the day-to-day concerns of the Public Safety services. However, during a wide-effect natural disaster, the need for such interoperability is greatly increased by the multiplicity of concurrent events.

k) The mitigation of the vulnerability of lack of interoperability is slowly being overcome as many systems are upgraded to shared trunked systems. An intrinsic element of such systems is the interoperability available between services and the capability of absorbing major variations in emergency traffic.

l) A reasonable assessment of the vulnerability of a network to a lack of interoperability can be obtained by identifying (in combination) if it is a trunked system and a shared system. Given however that the data sets for some Public Safety and Public Service networks are incomplete, a further indication can be obtained by the *age of system* data layer. For the *new systems* (i.e. those identified in the database as less than four years old), the likelihood of sharing and trunking is comparatively high. For those in their normal operational *lifetime* (i.e. from four to ten years old), the situation regarding sharing and trunking is very variable. However, with the obsolete systems (i.e. those over ten years old), the likelihood of trunking is extremely low, as is the likelihood of sharing.

m) Little work has been carried out to identify the vulnerabilities of mobile radio networks to natural hazards on a national basis, nor has it been carried out to classify the types, cultures, and limitations of Public Safety and Public Service networks on a national basis. This has resulted in the data being quite variable from province to province and from system to system.

9.0 Recommendations For Future Directions

From the conclusions drawn above and from the findings in general, the following recommendations are made for future directions and work:

- Every encouragement should be given to municipalities to upgrade their mobile radio networks to shared systems and, where the size of the system is appropriate, to strongly consider the trunked architecture approach. In addition, and where practical, the trend to use legacy networks as a back-up should be encouraged.

- Additional work should be carried out to attempt to quantify the impact of maintaining the *status quo* of mobile radio systems on the management of natural disasters. This should focus on municipal Public Safety and Public Service systems. It should also consider the importance of the lack of priority given (in most cases) by municipal and other Public Safety network managers to disruption by natural hazards.

- Training and simulations of natural hazards must be strongly encouraged, not only for the provincial and regional networks that currently have the highest level of training for natural disasters, but in particular for municipal networks outside of the *large city* category. This will identify vulnerabilities in the current systems and permit the consideration of mitigation options.

- In light of rapid changes related to municipal Public Safety systems in particular and private and public systems in general, it is recommended that data gathering on both the capabilities and vulnerabilities of mobile radio systems continue and be expanded upon. These data could be used to further populate the databases accompanying this report. By this means, knowledge of the networks will be improved so that they can be analyzed and their vulnerabilities mitigated.

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Appendix B – Database Information

Databases contain privileged information and may be made available for limited distribution on a per request basis only.

Private Networks By Province

Line Titles

B.C.

- Ministry of Forests – Province of B.C.
- Capital Regional District
- Greater Vancouver

Alberta

- Province of Alberta
- City of Calgary
- City of Edmonton

Saskatchewan

- City of Saskatoon
- City of Moose Jaw
- City of Regina

Manitoba

- Province of Manitoba

Ontario

- Province of Ontario
- City of Thunder Bay
- City of Sault Ste. Marie
- City of Sudbury
- City of Windsor
- City of London
- City of Owen Sound
- Niagara Region
- City of Kitchener-Waterloo
- City of Guelph
- New City of Hamilton
- Halton Region
- Peel Region
- City of Toronto
- City of Barrie
- York Region
- Durham Region
- City of Kawartha Lakes

- City of Cobourg
- City of Belleville
- City of Kingston
- City of Ottawa
- City of Cornwall

Québec

- Province of Québec
- City of Montréal

Nova Scotia

- Province of Nova Scotia

P.E.I.

- Province of PEI

Northwest Territories

- The Northwest Territories

Public Networks By Province

Line Titles

B.C.

- Bell Mobility – Cellular Digital
- Bell Mobility – Cellular Analogue
- Bell Mobility – PCS
- Telus – Cellular Analogue
- Telus – PCS
- Microcell – Cellular Analogue
- Rogers AT&T Wireless – Cellular Analogue
- Rogers AT&T Wireless – Cellular Digital
- Rogers AT&T Wireless – PCS

Alberta

- Bell Mobility – Cellular Analogue
- Bell Mobility – PCS
- Bell Mobility – Cellular Digital
- Microcell – Cellular Analogue
- Microcell – PCS
- Rogers AT&T Wireless – Cellular Analogue
- Rogers AT&T Wireless – Cellular Digital
- Rogers AT&T Wireless – PCS
- Telus – Cellular Analogue
- Telus – Wide Area Telus Enhanced Radio System (WATERS)

Saskatchewan

- SaskTel – Cellular Analogue
- SaskTel – PCS
- SaskTel Mobility – Trunked province-wide Ericsson (EDACS®)
- Telus – Cellular Analogue
- Microcell – Cellular Analogue
- Microcell – Cellular PCS
- Rogers AT&T Wireless – Cellular Analogue
- Rogers AT&T Wireless – Cellular PCS

Manitoba

- Rogers AT&T – Cellular Analogue
- Rogers AT&T – PCS
- Telus – Cellular Analogue
- Microcell – Cellular Analogue
- Microcell – PCS
- Manitoba Telephone Service (MTS) – Cellular Analogue
- Manitoba Telephone Service (MTS) – Cellular Digital
- MTS Mobility – Province-wide Motorola trunked analogue/digital SmartZone™

Ontario

- Bell Mobility – Cellular Analogue
- Bell Mobility – Cellular Digital
- Bell Mobility – PCS
- Microcell Communications – Cellular Analogue
- Microcell Communications – PCS
- Microcell – Cellular Analogue
- Microcell – Digital PCS
- Rogers AT&T – Cellular Analogue
- Telus – Cellular Analogue
- Telus – Digital PCS

Québec

- Microcell – Cellular Analogue
- Microcell – Digital PCS
- Bell Mobility – Cellular Analogue
- Bell Mobility – Cellular Digital
- Bell Mobility – Digital PCS
- Rogers AT&T Wireless – Cellular Analogue
- Rogers AT&T Wireless – Cellular Digital
- Telus – Cellular Analogue
- Telus – PCS

New Brunswick

- NB Tel Mobility – Cellular Analogue
- NB Tel Mobility – Digital PCS

Nova Scotia

- MTT – Cellular Analogue
- MTT – Digital PCS
- Telus – Digital PCS

P.E.I.

- Island Tel – Cellular Analogue
- Island Tel – Digital PCS
- Rogers AT&T Mobility – Cellular Analogue

Newfoundland

- NewTel – Cellular Analogue
- NewTel – Digital PCS

Data Columns in the Public Networks Database

- Province
- Type of System
- Type of Network
- Operating Entity
- Contact
- General Statement of Coverage
- Frequency Band
- Comments
- Potential Natural Hazards
- Source(s)
- Database Update Date

Public Paging Networks By Province

Line Titles

B.C.

- Omega Communications Ltd.

Alberta

- Telus Mobility
- Tridon Communications (Fort McMurray)
- Tridon Communications (Lloydminster)

Saskatchewan

- G+L Mobile Communications

Manitoba

- Integrated Messaging Inc.

Ontario

- Bell Mobility
- Madison Telecommunications Inc.
- The Message Centre
- Password Communications Inc.
- Rogers Wireless Inc.
- Telephone Answering Service (Quinte) Co. Ltd.
- Verizon Wireless Messaging Canada Ltd.
- Christie and Walther Communications Ltd.

Québec

- Communications Métro Montréal Inc./Télé-Page

Nova Scotia

- Digipage Communications
- DownEast Communications

Public Safety Licenses Issued Database

- From Industry Canada's TAFL Database